THE ELEMENTS OF

RAILWAY OPERATING ECONOMICS.

To the Railway Student, interested in his profession, its importance and its vast possibilities, this volume is respectfully dedicated.

THE ELEMENTS OF RAILWAY OPERATING ECONOMICS.

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CONTENTS.

PREFATORY NOTE.

This book, which, as its name implies, deals with the economics of practical railway operation, owes its being to the Authors' belief that there is a demand for a work which, neither too abstruse nor technical, discusses the railway business in its collective aspect of a producer, distributor, and seller of the commodity of transport.

Our endeavour has been to propound and discuss the application of economic theory to the railway business from a practical standpoint, a course which —we believe—has not so far been attempted (on these lines) in the whole range of railway literature. It is hoped in this way to direct the attention of the student to matters of serious importance in the railway world, as it is only by the comprehensive study of such problems and their practical application, that British railways will maintain their good name for scientific administration and operation.

Fully alive are we to the many limitations, omissions, and—mayhap—crudities of the present work, but if it will serve to indicate sources of research and data for more exhaustive and advanced study, our labours may not have been in vain.

We would add that portions of the matter contained in Chapters VI. and X. are reproduced from two articles on "Railway Rates," one of which we contributed to the "Financial and Commercial Supplement" of *The Times* in February last, and the other to *The Railway Times* in June, 1913, whilst Chapters II. and IV. include extracts from an article on "Passengers and Goods Train Operation" published in *The Railway News* in April of this year.

C. T., D. R. L., J. A. J.

Marylebone Station,
London, N.W.,
November 1913.

PREFATORY NOTE TO SECOND EDITION.

The gratifying reception accorded to this little work on its original publication, allied to the fact that a second edition has been called for within six months, indicates that there is a demand for a work dealing with the economics of practical railway operation.

The demand is not merely a local one, we are pleased to say, and in taking this opportunity of expressing our thanks to those members of the staffs of British railways who have so kindly brought the book before the notice of their colleagues, we would add our indebtedness to those others in far-off climes—America, Argentina, Africa, Japan, Russia, etc.—who have aided its circulation over an area far beyond our keenest anticipation.

C T., D. R. L., J. A. J.

Marylebone Station,
London, N.W.
June, 1914.

THE ELEMENTS OF RAILWAY OPERATING ECONOMICS.

Chapter I.—INTRODUCTION.

Historical Development—British Conditions—The Business of Transport—The Principles of Operation in Theory and Practice—The Economic Ideal.

Though Great Britain was practically the pioneer of the world's network of railways, English literature is deficient, as compared with that of other countries, in matters pertaining to transportation, and whilst, from time to time, books have been written on various sections of the business, few attempts have been made to discuss the principles of railway operation from an economic standpoint. We, therefore, introduce a short series of elementary papers on Railway Operating Economics, designed to consider on broad lines the close connection between the "specialised" road, the rolling stock, and actual transportation.

HISTORICAL DEVELOPMENT.

When it is remembered that within the short span of a human life all the activities of railway enterprise have fructified, it is worth while to contemplate the varying epochs, and briefly to consider how the railways have reached their present position.

Railway history may be roughly divided into three periods. In the first case, it is interesting to recall that the early railway companies were merely expected to construct the line, and leave the business of conveyance to the carriers of the time. Their responsibilities were definite. They provided and maintained the road, and received payment for the use of same in the shape of tolls.

Gradually, however, the position changed. The railway companies began to compete with the carriers for the conveyance of traffic, and, finally ousting them, established the second stage of economic development—the monopolisation of rail transport. At this time (i.e., during the period of Railway Mania, 1850-70) there were innumerable companies in existence, and these subsequently made a further move in the right direction by amalgamations which enabled them to conserve their strength, which otherwise would have been wasted in fruitless competition, for the development of their resources.

As time went on, the railway companies perceived that their operations could be profitably extended to other than ordinary railway business by specially attracting both passenger and goods traffic, and they established hotels at their termini for the convenience of passengers, outlets in the shape of docks to facilitate the export and import of merchandise and to act as feeders to the railway, fleets to convey passengers and goods to other countries at

through rates and fares, and the multifarious other auxiliaries inseparable from a modern railway undertaking—the third stage in railway history.

BRITISH CONDITIONS.

The peculiarity of British conditions may first be considered, as they differ in essential particulars from those of other countries. To state the fundamental characteristic of British railways we cannot do better than quote from "Railway Transportation," by G. L. Raper, an American writer, who says: "Great Britain is the most perfect example of strictly private railway corporation, and the greatest achievement of private ownership and operation." And this despite impeding legislation which, on the inauguration of railways, restricted their movement and has continued to do so to this day.

Whilst American railways have received from the public large sums of money in addition to grants of land amounting to 242,000 square miles, and other foreign railways have received similar assistance, British railways have received practically no assistance from the nation. And if this were not enough, if a great public service, such as this, were not deemed worthy of support, surely mature deliberation and thoughtful legislation might have enacted such measures as would have prevented railways being made the butt of the unscrupulous. But no: practically every inch of land secured by the railways for the purpose of effecting a public service had to be paid for "through the nose," and huge sums were disbursed in many cases to avoid the cost of litigation.

A typical example of public opposition to the new

form of transport, and its effect on capital cost, is afforded by the experience of the London and Birmingham Railway (now the London and North-Western). In constructing their line, they wished to pass through Northampton, that town being on the direct route, yet such a protest was raised that they were able to ward off opposition only by promising that their line should not pass within 5 miles of the town, this deviation necessitating the boring of Kilsby Tunnel, at a cost of £300,000.

Such considerations as these have exercised a powerful influence on railway operating costs and charges, as the rate charged for service, under normal conditions, must include a contribution to interest on capital and fixed charges, and cover its own operating cost. In general terms, therefore, the higher the capital cost the heavier the rate to be charged, and thus British railways have been forced to levy higher rates than those which would have been remunerative were it not for the necessary payment of interest on such high and uneconomical capital cost.

Much more could be said of capital cost, and its effect on railway rates, but as, generally speaking, it is outside the scope of these articles, it will be touched but lightly. It should, however, be pointed out that the relatively high burden of capital cost is reduced in direct ratio to the increase in traffic density, as each additional unit of traffic at normal rates contributes its quota to the fixed charges, whilst traffic conveyed below normal rates contributes in some measure to the general charges immediately its own transportation cost, or as Colson, the eminent French economist, terms it, "the additional net cost," is covered.

The greater the density of traffic, however, the more urgent becomes the need for scientific operation, and thus one has to consider

THE BUSINESS OF TRANSPORT.

The business of transport being primarily the movement and conveyance of products and commodities from points of origin and manufacture to marketable spheres, it follows that transport has a certain definite value, relatively high or low, according to the difference in the market price at the two localities. Of this access of value the railway obtains a share, but not a proportionate share in all cases, for transport charges vary not only in accordance with the cost of operation, but according to the value of the service and to what the traffic will bear. Prices determined on these bases will give the traffic such scope of development, as will lead—other things being equal—to profitable operation, for operating cost may lie heavily on a few units of traffic, but spread over many units it is reduced in significance.

We are then able to say that a railway produces transportation, a commodity which its organisation distributes for sale, and, though the statement requires modification in varying degrees, it is necessary that there should be a profit on the transaction, or the production of transportation, to prevent cessation, would have to be subsidised. It would seriously retard the material prosperity of the country were such a contingency to arise, as the development of trade and industry, owing to the absolute interdependence of their various branches—a state of affairs due to the ubiquity of transport—is

only permissible correlatively with the continuation of economic transportation facilities.

When it is considered, in addition, that the general tendency of railway expenditure is always towards its augmentation (i.e., additional services, plant and accommodation), it is manifest, from the very nature of things, that the problem of transportation is of vital national interest. Thus, then, we are faced with the following situation: Accelerated and more frequent services of passenger and goods trains, together with additional facilities, are more and more desired; large and increasing volumes of traffic are thrown upon the railways; Parliamentary control is ever justifiably keen in its requirements for safety, and rates must, in themselves, bear a very small proportion of the increase of value of any transported commodity.

Now, it is obvious that the first requirement can only be satisfied if some reasonable expectation of the second factor is realised. In conjunction with the third point, however, there may be a difficulty, for a line may be utilised to its maximum safe working capacity, and bringing in the necessity for low rates, the difficulty is intensified, for it would not be expedient for a railway company to increase its facilities by widening the lines, providing additional accommodation, etc., unless there were some prospect of its being recouped for the outlay.

It is essential, therefore, for the management always to endeavour to conduct the business with its existing facilities, and until such time as the flow of traffic warrants the extension of accommodation, additional revenue-earning traffic can only be economically worked by the adoption of scientific methods of operation, though these, of course, are

influenced by physical conditions and general principles. The greater the economy in operation, therefore, the longer will the existing facilities suffice.

THE PRINCIPLES OF OPERATION IN THEORY AND PRACTICE.

In a recent lecture a well-known general manager said : " . . . But for the construction of a few comparatively short lines here and there, the railway system may be considered complete . . ." and, working from this basis, we may take it that the problems of operation will become increasingly difficult.

With the large volumes of traffic now being poured on the railways, those responsible for traffic manipulation have to exercise all possible ingenuity to conduct the work efficiently, particularly when both passenger and goods traffic has to be accommodated on a double line of metals. For it must be clear that the large increases in goods traffic necessitate the formation of longer and heavier trains, and as these will not travel at the same speed as lighter trains, the difficulty of working them with the regular passenger service is increased.

The logical way out of the difficulty would appear to be the widening of lines, but as, generally, the congested points are either in proximity to large industrial towns where suburban passenger services must be maintained, or at points of the line where, owing to physical conditions, high expenditure would be necessary to effect improvement, there are several facts to be noted.

In the first case it will be apparent that the mere fact of a main line running through a town results in the erection of factories, warehouses, and works

contiguous thereto, some in order that they might obtain siding connections, and others for the various facilities offered by the railways. This fact, which necessarily means that the land is extremely valuable, may render the cost of widening prohibitive.

By the adoption of power signalling, it is possible to accelerate the movement of trains somewhat, inasmuch as smaller margins are required to clear the block posts, but this is only a temporary measure. It would, therefore, appear that the most economic method of facilitating operation through particularly congested areas is by the provision of avoiding lines for through traffic, as by this means previously existing lines may be reserved exclusively for passenger traffic, and for goods and mineral traffic destined for the particular area.

THE ECONOMIC IDEAL.

The whole economic proposition of successful operation is the realisation of the highest possible ratio of effective work to the unit of cost, and it is in the endeavour to analyse the various problems connected with the strain after perfection that this series has been written.

At the outset it is important to observe, as Professor Ripley points out in his "Railroads, Rates and Regulation," "that a railway theoretically presents a clear example of an industry subject to the law of increasing returns—that is to say, an industry in which the cost of operation grows less rapidly than the volume of work done."

Each ton of traffic added to the existing traffic costs relatively less to haul, and from this it obviously follows that the net returns increase more than proportionately with the expansion of traffic, such

expansion of traffic, of course, being always considered as within the limit fixed by the total amount of traffic with which the accommodation of the railway can economically cope. For it must not be forgotten that a railway, unlike many other industries, is distributing its operation over the entire twenty-four hours of the day. Whilst, therefore, the limit of full working capacity in a factory is elastic, by reason of the fact that it may, when necessary, prolong its operations beyond the normal hours, a railway enjoys no such expansible limits upon utilisation of plant.

The law of increasing returns must, however, be qualified, as it is only relatively true to say that fixed charges are practically constant. Ripley's apt phrase, "Many expenses follow the fluctuations of business, not evenly but by jerks," pithily summarises this tendency. Until the existing facilities are utilised to the highest effective point, each increment of traffic merely necessitates a small and disproportionate augmentation of the operating expenses with but slight alteration in the fixed charges, and the law of increasing returns applies; but immediately an increase of traffic necessitates the provision of additional plant or accommodation, the law of increasing returns ceases to apply until such time as the revenue from the additional traffic entirely covers the cost of the facilities; then, and afterwards, of course, it applies with greater force than before.

The economic ideal is, then, to secure the highest effective utilisation of the plant and equipment—to satisfactorily conduct, by means of scientific methods, the business offered with the existing rails, terminals and rolling stock.

Chapter II.—PASSENGER TRAFFIC.

Services and Fares—Passenger Train Operation—Timings and Punctuality—Loads, Speeds, Grades and Conditions—General Considerations.

The business of transport being of such a vast and complex nature, it is difficult accurately to portray any of its many phases without remarking on some of its dependent factors, hence this and subsequent articles which purport to deal with transport in its fundamental duty of traffic manipulation must be regarded collectively.

In the consideration of train operation, one immediately meets with the question as to how the work can best be adequately, but concisely, described, having regard to its many ramifications; how and where to comment upon the costs of the various services, and upon the revenue derived therefrom; moreover, the necessity of discussing the many pressing problems in a comprehensive manner, and yet analysing each phase in its relation to the many influencing factors, which have a somewhat general application, renders a certain amount of reiteration inevitable.

There is, however, one natural and logical line of demarcation—that between passenger and goods train operation—and we shall treat these separately so far as is consistent with due clarity and explanation, though it must be remembered, in connection

with "user of the road," that the two services merge in the operation of "perishable" trains, and, to some extent, in that of express goods trains. It will be well, therefore, to discuss the subject under various heads, reference being made, where necessary, to establish the essential connection between them.

SERVICES AND FARES.

The special attributes of a good passenger service are (a) punctuality, (b) adequate connections from local to through services and vice versa, and (c) departure and arrival times suitable to the class of traffic which the trains are intended to convey. But more than this is required by the public, who, favoured by the railways—through stress of competition—with well-designed and luxuriously appointed carriages, conveniences for dining and taking refreshment *en route,* and high speed of travel, tend to make demands more and more insistent.

In dealing with this subject we are confronted with the question as to what constitutes a good service between two important centres of population. To solve this question with exactness, however, we should be compelled to take each pair of important towns separately and discuss the service of trains between them, having due regard to the interests of the places served and the numerous local conditions under which the traffic of each particular district is worked. Further, the quality of service may have different meanings as between the railways and the public. The latter require a frequent train service, and whilst this must exist, to some extent, if additional traffic is to be attracted, its

provision is not, in many cases, to the benefit of railway revenue.

The various railways naturally differ in the extent of the facilities they offer, the introduction or exclusion of which is largely dependent on the special conditions of each line and the particular class of traffic carried. For instance, it would be highly undesirable to run trains with a preponderance of first-class carriages in colliery districts, and, similarly, to restrict suitable stock in districts having a potential high-class traffic.

The question of dining-car facilities will be described in a later section, but it might here be said that suitable consideration should be given to these services, as, having regard to the expense involved, their uneconomic provision and operation will quickly lead to serious waste and loss.

The passenger service may be divided into three sections, viz., (1) express, (2) local or stopping, and (3) suburban, the last of which will, on account of its special nature, be treated separately. Revenue derived from passenger trains consists chiefly of passenger fares, which may roughly be classified into three divisions, viz., ordinary fares, excursion fares by ordinary trains, and excursion fares by special trains.

Ordinary passenger traffic utilises the regular train service, and is composed of persons who, for business or other reasons, find it necessary to travel, and, in some cases, persons who for the additional comfort of travel will pay the ordinary fare rather than be crowded and inconvenienced in the special trains. Excursion fares, however, are put into operation in order to tap a source of traffic composed of people who otherwise would not leave their

homes, or at any rate would not venture so far afield. Many units of the ordinary traffic, i.e., persons who are bound to travel, take advantage of such fares, however, and it is for the railway manager, when introducing an excursion fare between any two points, to consider whether the additional low-rated traffic will more than counterbalance the loss occasioned by the transfer of otherwise high-rated traffic to the low-rated; this proposition has particularly to be considered before the introduction of cheap tickets available by ordinary trains.

The running of special excursion trains in connection with sporting or other events will generally be warranted if the proceeds leave a margin after covering entire working costs, it being assumed that very few passengers would travel between the points concerned were ordinary fares charged.

The facts to be considered are that ordinary trains must be run to meet the demands of the public, and if extra traffic can be attracted to them by low fares the receipts from the additional traffic represent profit; similarly, when specials are run, many of the operating expenses are but slightly affected, and so long as the revenue from the traffic exceeds the cost of providing engine, rolling stock and train crew, the transaction may be regarded as profitable, always provided that special excursions do not cause such extra delay to freight and other trains as will result in a wastage of engine power, trainmen's wages, etc., to counterbalance otherwise profitable sale of transport.

Revenue accruing from passenger train services other than that through the medium of passenger fares is derived from parcels traffic. Although (with the exception of a few classes of perishable goods)

there is no statutory compulsion upon the companies to carry this traffic by any other than goods trains, it is conveyed by passenger trains in consideration of the payment of charges higher than those embodied in the goods rates, for the additional facilities provided. This traffic necessitates considerable expenditure in clerical work and general labour, but having regard to its conduct and conveyance by the existing train service, and to the expense that would be involved in transhipping and in the running of light-loaded wagons were it conveyed by goods train, it may, generally speaking, be looked upon as profitable.

The operation of passenger trains over lines passing through sparsely populated districts is a matter calling for careful consideration. The normal passenger traffic may not warrant more than a very limited number of trains each day, but there is a possibility that, by increasing the number of trains and generally improving the service within, of course, certain limits, a larger number of passengers may be attracted. In most cases, the number likely to be attracted, or possible of attraction, does not warrant additional trains of the ordinary type, but may demand a more frequent method of transport at more frequent intervals; this fact has created the introduction of steam and petrol-electric motor cars, which, in addition to costing less per mile to operate, render possible the issue and collection of tickets on the journey, thereby reducing station expenses by the employment of but one stationmaster to control two or more stations. This method of economy can, however, only be applied where the whole service of trains on the branch consists of motors, and where business connected with the

goods traffic is not such as to warrant the constant presence of a stationmaster at each station or depot.

It must not, however, be overlooked that the utilisation of motor transport for passengers has a disadvantage in the fact that the cars can only be used for the one purpose, and are not, therefore, interchangeable with the ordinary rolling stock. Nevertheless, such a train service may have the effect of so increasing the prosperity of a district as to warrant, at a later date, the running of ordinary trains, with the logical sequence of an increased goods traffic.

PASSENGER TRAIN OPERATION.

Transportation may consist in the movement of persons or of things, and whilst we have briefly outlined the necessities of the passenger service, it is necessary first to describe the requirements of general operation before we can explain the relationship between the two distinct traffics; the varying character of the conditions affected and prevailing; and the complexities and peculiarities of the circumstances under which, on the one hand, the public require frequent and regular services of trains coupled with low fares, and, on the other hand, the railways attempt to lessen the wide margin of expense between the cost of maintaining an efficient and adequate service and of unduly succumbing to public demands.

It is impossible to lay down any definite rules for the regulation of passenger train operation since conditions vary so considerably between different lines, and even between different districts on the same line. Rules applicable for operation on a level

road would be quite unsuitable for traffic over heavy grades, and any general statements made respecting the working of traffic on a line serving a large industrial area would have no bearing at all on the operation of trains between (say) a large industrial centre and a popular seaside resort.

Certain general statements can, however, be introduced and analysed in a discussion as to the method of reducing the amount of unprofitable haulage to a minimum, whilst accommodating to the fullest extent reasonable requirements on the part of the travelling public; how to secure the best paying loads and preserve a fair margin of profit for those whose capital is invested in the railway business.

Ideally, all block sections on a line would be the same length, the road would be level, and all trains run at the same speed. Such Utopian conditions, unfortunately, do not exist on the main railways of Britain, and even if the road were all that could be desired, it would be impossible to couple in the element of economy the factor of equal speed. For passenger requirements are distinguished particularly by their variety. If expresses are introduced there is usually some "disinterested" individual who petitions for a particular train to stop at some wayside station or other, whilst, on the other hand, where stopping trains are scheduled between important towns, passengers lament the (to them) poor service in their ignorance of the fact that the trains are not "through" trains in the literal sense, but merely sectional conveyances.

The theory of an ideal line, indeed, brings to light an important economic fact: that on a line of high traffic density all trains—goods and passenger—

should run as nearly as possible at the same speed, the passenger trains as slowly as the pressure of competition and the demands of the public will permit, and the goods trains as fast as their loads and other circumstances will allow.

With the varying elements of modern traffic, however, such economic movement is impossible, operating arrangements having to be accommodated, to quote from Findlay's "Working and Management of an English Railway," to such differing conditions as are presented by express passenger trains running at 45-60 miles an hour; others at a somewhat less speed, but still known as fast trains; stopping trains, calling at every station; high-speed short-distance suburban trains; express goods trains between the principal towns; slow, stopping goods trains, for serving smaller towns and villages; and, finally, the heavy coal trains, running out of the great colliery districts to the large centres of population and various ports.

All these trains, heavy and light, fast and slow, some stopping at stations, others dashing through them, have to be accommodated to a great extent upon the same line of metals, yet all must keep their time and fulfil their appointed functions. This, then, is the problem of operation.

TIMINGS AND PUNCTUALITY.

One of the most difficult subjects in the entire field of railway operation is the construction of a proper system governing the movement of trains. It would be impossible, and even if possible, impracticable, to give specific instructions to each train, and time-books are therefore prepared. So

far as it is possible to solve the problem by preconcerted arrangement this is done by the provision of schedules giving the times of departure of trains, time due at various points en route, and times of arrival.

The timing of both passenger and goods trains must necessarily be determined *en bloc,* as no reasonable and adequate service could be initiated if one were considered to the exclusion of the other. As, however, in this article we are primarily concerned with passenger trains, we will now consider the general laws governing the scheduling of the express and slow trains used for this traffic.

En passant, it might be remarked that if the theory of the time-book, with its regularly appointed trains running at varying rates of speed, with specified places for them to pass each other, could be realised in regular practice, it would represent the perfection of railway working; but, owing to the variable climatic conditions, the fluctuations of traffic, the necessity of running special trains at short notice, and other uncontrollable factors, this ideal can never absolutely be attained. Generally speaking, the most important consideration is to keep the line clear for passenger trains, and though they may not, in the majority of cases, be as productive, from a revenue-earning point of view, as their less speedy contemporaries, their operation must be given preferential treatment. For the public are apt to judge by the obvious, and a well-appointed and punctual passenger service is calculated, above all other things, to enhance the reputation of a company.

This brings us, then, to the particular consideration of punctuality. It is generally understood that

the punctuality or otherwise of passenger trains affords, to a considerable degree, the measure of support they receive from the public. This is, of course, as it should be. Trains are scheduled to start from station A, leave station B, and arrive at station C at certain definite times, and whilst, unfortunately, railways all over the world, under prevailing conditions, have great difficulty in keeping their trains, particularly expresses, strictly to time, it is only to be expected that the public will patronise the line which will give the most punctual operation, compatible with regular service and necessary facilities. The causes of delay are so numerous—some technical, others practical—that it is impossible to enumerate them, but the most important are (1) waiting connections, (2) standing at signals, and (3) overtime at stations. Since such delays, where they might be avoided, represent clear and actual economic waste, a consideration of the question of timings and various influencing factors is essential.

Express and local trains should be considered in their relation to each other so that stopping trains may feed expresses, and, similarly, expresses feed other stopping trains. Considerable ingenuity is demanded in scheduling stopping trains so that they may, with as little delay as possible, carry forward passengers brought in by one express at a point A, and feed, if necessary, a following express at a point B. To a great extent the scheduling of expresses must be arranged at times convenient to through passengers and the stopping trains timed to harmonise with them, but this does not operate in all circumstances.

Connections should always be given a reasonable

margin (say, fifteen minutes), as unless this be done delays to stopping trains may reflect on expresses, and unpunctual expresses may interfere with the working of connecting local trains. It is, in fact, stated that on one occasion the late arrival of a south-bound express in London was indirectly caused by the late running of a north-bound express the previous day. This may be exceptional, but it serves, nevertheless, as an indication of the possible results attendant on the fine timing of connections.

The schedules should also be such as to permit of the running of duplicate, relief, or fast special trains immediately before or after expresses without interfering with the working of slow passenger trains. If a fifteen minutes margin be allowed between a fast and a slow train, a special may be worked between them; but if the margin be only five minutes an excursion or special train cannot be run without serious risk of interference to other trains. Wherever possible, stopping trains should be given a fairly easy timing, in order to provide for unforeseen circumstances, and any special delays such as those accruing from attaching or detaching horse-boxes, heavy luggage and parcels traffic, etc. Where such contingencies as attaching or detaching vehicles take place the lay-out of the station may adversely affect the economic handling of traffic, and whilst, in such cases, the rectification of existing plans would probably mean high capital expenditure, renewals and new constructional work should, when in embryo, receive the approval of all officers directly or indirectly concerned with the operation of trains.

Train services, particularly in districts of high traffic density, should be scientifically scheduled so

that the greatest possible use may be made of the line and of existing running loops, etc. Some companies consider it advisable to prepare " working diagrams," showing the throughout timings and progress of each train from start to finish in the various districts of operation. This certainly tends towards scientific scheduling in the fact that the advantages or disadvantages of timing a given train earlier or later may be seen at a glance. The practice is not, however, generally adopted, some companies considering that their train clerks and officials, being thoroughly conversant with the scheduled running over their respective districts, will in all cases refrain from so timing trains that they delay each other en route or at junction crossing points. The latter point may easily be overlooked, and whilst it is of minor importance where " flying " or " burrowing " junctions are provided, care is required in the case of crossing junctions.

Another fundamental point to be considered in connection with schedules is that when an outward journey is run, a return journey is rendered necessary, otherwise light engine running ensues. The latter is seldom economical, as, however small the receipts from the return train, they probably represent profit, the operating expenses being very little more than those of a light engine, and the possibilities are that an engine working a booked passenger train will arrive home in less time than a light engine, owing to the greater importance attached to the headlights.

From a railway company's standpoint, punctual working is always advisable, and, generally speaking, travellers prefer a prompt arrival time at destination though the running time be generous,

rather than tight schedules and uncertain arrival times. Those responsible for the working are, therefore, constantly engaged in a contest against disturbing influences, and the arrangements have, necessarily, to be sufficiently elastic to enable trains to be run out of course as safely and well as at the specified times.

LOADS, SPEEDS, GRADES, AND CONDITIONS.

The increased facilities now offered to passengers in the shape of superior accommodation and high speed of travel have thrown a tax on the railways in their endeavour to maintain the traffic with a reasonable amount of profit. The division of carriages into classes, compartments for women, for smokers, etc., makes the complete utilisation of stock extremely improbable, since if one compartment or set of compartments is full, it by no means follows that other compartments are similarly filled. These divisions, therefore, assist materially to raise the ratio of dead weight to paying weight, and when the provision of corridor stock, lavatories, dining, and sleeping cars is considered, it is apparent that the dead weight is a formidable quantity, even if every unit of seating capacity be occupied.

A noticeable feature in the passenger traffic question is the diminution in the average length of trip. In the freight traffic the general tendency is towards a longer haul, with the greater concentration of industry and the widening of the markets of the world. At the same time, there is a tendency towards the running of more lightly loaded passenger trains, and upon the whole the number of passengers per train, and the proportion of occupied

to unoccupied seats seem to be diminishing. This condition, also, is directly opposed to that observed in the freight traffic, where train loads are increasing with wonderful rapidity and the proportion of net weight to tare constantly improving.

The demands made by passengers for comfort, speed, safety, and convenience of travel have been increased, so that the service of to-day is far superior to that of previous decades, and in this connection we may give expression to the axiom that the greater the extraneous accommodation—utilised for lavatories, vestibules, etc.—the smaller the proportion of passengers seated to those left standing. The more frequent the scheduled trains, the poorer the economy of carriage capacity. In fact, it may be to the immediate interest of the railway to give the public a quite inadequate service in order to utilise the rolling stock better, but this may be done to the detriment of the railway. But the correspondence between the effective use of the carriages and a poorer service may easily be demonstrated.*

Causes of the poor utilisation of carriages are not far to seek. Many of them are inherent in the character of the traffic. Even if every seat were always occupied, the proportion of dead weight to paying weight would be far greater than in freight traffic. Passengers cannot be detained for hours until a sufficient number is collected at the stations. Trains must run on schedule time, either full or empty, and no amount of ingenuity can predetermine exactly the demands to be made in a given place and at a given time upon the rolling stock of a company.

* "Passenger Traffic on Railways." W. E. Weyl.

The utilisation of carriages is also injuriously affected by the great variations in the density of traffic. As Weyl, the American economist, neatly expresses it in his book on passenger traffic, the traffic is very dense in the neighbourhood of a large city, and the utilisation of the carriages therefore high, but with increasing distance the use of the seating capacity of the carriages becomes less and less. New passengers enter the carriages, but in insufficient numbers to make up for the departure of others, since it may be said, in a general way, that a city attracts travellers from its neighbourhood directly in proportion to its size and inversely in proportion to the intervening distance. For this reason it is usually expedient to separate the through local from the through express traffic.

Developments in passenger travelling facilities, some of which are connected with an improved service, tend towards a decline in the remuneration per unit of service as well as towards a smaller revenue from the passenger as compared with the freight traffic. It is not in the purchase of carriages, however, but in their use that the real expense lies. Their use consists of two elements; the number of carriages to a train and the number of passengers to a carriage. It cannot be supposed that any engine can haul an indefinite number of carriages. There is an absolute limit to the hauling power of a locomotive, but the more important limit is placed by the requirement of speed.

At a given rate of speed, and upon a road with a definite ruling gradient, a locomotive cannot haul more than a given number of carriages, and even before this point is reached, an increase in the proportion of carriages is accompanied by a corre-

sponding increase in the cost of the motive power. The limit which is laid by speed upon the number of carriages is still further reduced by the demands for comfort on the part of the passengers. The demand for room is a variable factor in different countries, and it may be said, as a rule, that the people who demand speed are not necessarily those who require comfort. Where the one consideration must be sacrificed to the other, a decision is made in favour of one alternative in some countries and of the other alternative in other countries.*

Speed is an element of cost, and it would be expensive to run ordinary trains at high velocity. Mr. Delano, in a paper delivered at the Western Railway Club of the United States at Chicago, said there were six sources of extra expenditure due to high speeds :—†

(1) Increased fuel consumption;

(2) Necessity for better and more expensive rolling stock;

(3) Increased wear and tear;

(4) Increased risk of accident by failure of rolling stock or permanent way;

(5) Augmented risk of collision;

(6) Delay to traffic entailed to keep road clear for high speed trains;

and it is, therefore, abundantly clear, as S. C. Williams observes, in his admirable book, "The Economics of Railway Transport," that the real working capacity depends on many factors, and alteration in any one involves alteration in one or

* "Passenger Traffic on Railways." W. E. Weyl.

† P. 103, "Railways." E. R. McDermott.

more of the remainder. The chief of these factors are:—

> Dimensions of stock;
> Average speed;
> Amount of power utilised;

and it will be found, in any detailed analysis, that the reciprocal action of these variables must never be lost sight of.

A later article on rolling stock will discuss the tendency towards increasing dead weight and diminishing capacity of vehicles, and the point will not, therefore, be further discussed here.

The increase in dead weight and reduction in capacity is not the full measure of the disadvantages under which the railway managers of to-day have to work. Besides having to run heavier trains, they have to run them at much higher speeds. It would be useless to recapitulate particulars of the accelerations which have been effected in British passenger trains during the last generation. Such information is general knowledge. But it is interesting to observe that the methods by which such accelerations have been effected—increasing the running speed, and eliminating intermediate stops—represent increased expense.

The higher the average of speed the stronger must be the permanent way and bridges, in order to withstand the severe strains to which they are subjected, and the heavier must be the capital outlay for construction. Greater expenditure in labour and material, again, is necessary to meet the wear and tear, and the larger locomotives which must be employed cost more to build and more to maintain

in addition to causing increased consumption of coal, water and oil. Further, the elimination of previously existing intermediate stops must tend to increase the train mileage, for in many cases new trains must be put on to serve the places omitted by the through trains.

With fares on the same level it will be clear that the railways have a somewhat stiff task to adjust the balance between supply and demand. On the other hand, it is urged that even the best speeds of the present day are not good enough, and it is suggested that railways would find an acceleration to (say) 70 miles an hour to their advantage, because quick trains attract passengers while increasing the capacity of the line. That they attract traffic in the sense that most travellers choose the fastest trains at their disposal may be admitted, but that they create new traffic to any appreciable extent is doubtful. For only a limited number of people require to travel, and the number of those wishing to do so is not capable of indefinite expansion, merely by the expedient of running trains at 70 miles instead of 50 miles an hour.

As to the capacity of the line being increased, this would only be possible if all the trains, goods and passenger, could be run at proportionately increased rates of speed. But such equality of speed is admitted to be quite out of the question; yet the introduction of a few very fast trains would simply emphasise the inequality of speeds, which is the great trouble on a line of high traffic density. As already indicated, the capacity of a line is greatest when every train runs at the same speed, and the greater the departure from the mean, either in excess or defect, the more is its capacity and carrying

power impaired; for whilst it is true to say that a very fast train leaves the line clear behind it more quickly than a slow one, it also requires the line clear for a much greater distance ahead. The greater the inequality of speed, therefore, the fewer is the number of trains that can be passed over a given distance in a given time.*

Further, any increase in the speed of trains would mean the aggravation of the resistance which grades and curves offer. In the early days British engineers anticipated this difficulty to some extent, and went to considerable expense to avoid heavy grades and sharp curves, but it is worthy of note that in countries where the possibilities of railway development were not so dependable as in Britain such great efforts were not made to reduce grades. That the great disadvantage of such heavy grades is now realised is, however, apparent from the re-alignment through Kicking Horse Pass, Canada, where the constructional engineers introduced a bank 4 miles in length on a grade practically 1 in 10, this necessitating the employment of five and sometimes six engines for a passenger train. This grade has now been reduced to 1 in 45, but the length of the bank has been doubled.

Grades and curves should not exist except where absolutely necessary, and superelevations on the latter should be sufficient to permit of smart running over them. Unless the track be kept in good condition running is impeded, and in all probability, if maintenance is not up to date, speed restrictions will, sooner or later, become necessary, at any rate temporarily. In such matters the requirements of

* "British Railways." H. M. Ross, B.A.

safety alone necessitate care, but economy also demands it.

Besides the influence of grades and, to a less extent, curves, the primary factor affecting the speed and loading of passenger trains is the locomotive; moreover, the determination of the most economical load is practically impossible owing to the considerable variation in conditions, not only in different seasons, but even at different periods of the same day.

Generally speaking, passenger trains are not loaded to the limit of the hauling power of the locomotive; firstly, because in this country there is a demand for frequent services between the same points, which naturally tend to reduce the number of passengers per train, and secondly, in the attempt to ensure punctuality, unforeseen circumstances must be provided for.

Whilst the suitability of locomotives and rolling stock will be discussed in future papers, we may here allude to the necessity for the suitable provision of brake-vans for the conveyance of luggage and parcels. By certain trains, especially to holiday resorts, passengers generally take with them a considerable quantity of luggage and unless liberal accommodation be provided, delays at stations will occur. It is probably on this account that the "P.L.A." arrangement was instituted, for it has a tendency to reduce the amount of luggage which otherwise would have to be carried by particular trains and enables the companies to dispatch it by such trains as can most easily accommodate the traffic, besides providing a source of revenue which, though small, would be unobtainable were the luggage accompanied by its owners.

GENERAL CONSIDERATIONS.

The length of sections has a considerable effect on operation; for example, if a 2-mile section be situated between two others each 1 mile in length, the value of the latter two is considerably impaired. To a great extent the situation of block posts is decided by the position of stations, junctions, and level crossings, but the first method of providing relief should the density of traffic reach such a point as to create delays would be the installation of an additional block box in the 2-mile section, or the provision of automatic block signals, in order to equalise the length of contiguous sections. As an alternative, it may be advisable by means of diagrams to analyse the trains passing over the area of density, and thus discover the periods of the day during which there is a less than average flow of traffic, this rendering possible the more even distribution of operation by the transfer of unimportant goods and mineral trains to the relatively low density period.

Structural details have also to be borne in mind, as it is, for example, highly undesirable to have stations with such short platforms as to compel passenger trains, in setting down and picking up passengers, to "draw up." If trains of such length be scheduled at the usual timings delay is bound to accrue unless passengers for the short platformed stations can be concentrated towards one end of the train, preferably the rear. Horse and carriage docks should be readily accessible from the main line, so that undue delays do not occur, but the influence of these factors will be more fully discussed later.

A further and final point calling for present con-

sideration in connection with passenger train operation, is the ratio of ineffective to effective work of train locomotives. This, of course, is a factor of far greater moment in goods train operation, but the possibility of laxity producing waste demands that the question should be discussed here. It may be said that the standing time of passenger train locomotives takes place only between the termination of one trip and the commencement of the next. Every effort should be made to reduce such standing time to a minimum, and not only should the number of train miles be studied, but also the number of engine hours required to complete such train miles. Further, when any alteration in the passenger service is proposed, due attention should be paid to the possibility of increasing the service without increasing the engine hours, and, in this connection, it may generally be said that there is no considerable advantage in reducing train mileage unless the engine hours can be commensurately decreased.

The necessity for keen supervision of the margins allowed engines at terminal stations prior to working trains is also worthy of attention. Some margin, of course, is essential, and this, especially in the case of express passenger train engines, should not, for various reasons, be stinted, but in all instances these margins should be cut down to the lowest point compatible with efficiency of operation.

Chapter III.—PASSENGER TRAFFIC.—(*Contd.*)

Analysis of Passenger Traffic—The Suburban Traffic Problem.

Passenger traffic differs from freight traffic in the fact that passengers are animate beings, and, having feelings which must be regarded, require safety, comfort and speed in their transportation. Safety is, of course, vitally essential, and this is ensured as far as possible by the employment of automatically acting brakes, and the block system of signalling with its adjuncts, track circuits, interlocking, etc., whilst stringent administrative regulations are in force. That railways must pay special consideration to measures designed to promote safety in operation is essential, not only for humanitarian reasons—though they would be all-sufficient—but in their own interests, because the huge amounts paid as compensation following accidents represent entirely unproductive expenditure, and where the accident is avoidable, absolute economic waste.

ANALYSIS OF PASSENGER TRAFFIC.

A most debatable question is whether passenger traffic or the transport of goods is the more remunerative to a railway, and an equally interesting point as to whether the working of passenger traffic, in Great Britain, is as remunerative as it might and ought to be. One authority maintains that the trans-

port of goods and especially of minerals is not only not remunerative, but is carried on at positive loss. Another authority makes the claim that goods, and especially mineral, traffic is the more lucrative, and that both are made to pay for the losses incurred in passenger transport. The problem would, therefore, appear to be one of the most knotty and unsettled points in railway administration.

The question is often asked: "Is the passenger traffic profitable to the railways, or is it operated at a loss?" The point of the whole difficulty is in the matter of joint costs. To be profitable, the operation of a railway must primarily bring in net receipts greater than the expenses it involves. Whilst the receipts derived from the passenger traffic are kept separate and are usually calculable, the expenses thereof are inextricably interwoven with those of the freight service, and it is impossible to say in what manner any particular costs should be divided between passenger and freight traffic.*

The amount of passenger traffic increases not only with the population of the country, but with the density of that population, with the number of cities, the preponderance of industrial over agricultural population, and with the wealth and general standard of intelligence of the country. There are many factors influencing the volume of passenger traffic. The variations in the seasons exert a great influence upon the volume of traffic, there being a remarkable similarity for years at a time in the proportion of the traffic conveyed in any given month, the variation usually being due to great changes in the weather. There is also a remarkable

* "The Passenger Traffic on Railways." W. E. Weyl.

similarity in the balance of passenger traffic in opposite directions, whereas the preponderating proportion of the freight traffic flows in one direction.

Up to a few years ago, most railways provided first, second and third class accommodation for passengers, but owing to the gradual improvement of the third-class carriage, and the desire of travellers for cheap transport rather than additional comfort, coupled with the probability of effecting economy in haulage costs consequent on the reduction of classes, the companies have, one by one, abolished the second class until now only two or three companies retain it on other than suburban services. This tendency of passenger traffic to lower classes is paralleled in the freight traffic where the transportation of the heavier, bulkier and cheaper commodities has grown at a much more rapid rate than that of the lighter and more valuable commodities. The cause is, in both cases, the same. With every improvement in the facilities, the railway has widened its sphere of usefulness, and has performed services in which the margin of profit is less.

The cost of operation depends only in a small degree upon the number of carriages running; in fact, a good utilisation of stock is accomplished in many cases only by giving the poorest conceivable service consistent with securing the traffic. The chief cause of the poor utilisation of passenger carriage capacity is to be found in the character of the service. The poorer the service, the better is apt to be the utilisation of the carriages. Speed does not permit the filling of trains, although it exercises a limit on the number of carriages hauled. The special reductions on return tickets, excursions, etc., are often considered arbitrary, but this is

wrong; they serve to raise the standard of utility of seating capacity which otherwise might be unoccupied, and it is but reasonable that railway administrations should offer special conditions to particular forms of travel likely to be most influenced by diminutions in the fares, traffic which, moreover, most easily responds to stimulation and which, in other words, has the greatest elasticity of demand.

The only interests materially involved are those of the railway and the travelling public, and *pari passu* the question of passenger policy resolves itself largely into one of the amount of the fare and the quality of the service. Where passenger fares have been reduced the usual result has been an increase in the traffic which more than compensates for the reduction. This rule, however, is neither general nor absolute, and the effect when beneficial is not always immediate or capable of exact statistical calculation.

The general rule (which holds good for the prices of nearly all services and commodities) is that a reduction in price will call forth an increase in demand, and, in the railway service, the greater the demand the less the cost at which each part of it can be satisfied. Certain forms and kinds of passenger traffic, however, are more susceptible to stimulation; in other words, respond more readily to a reduction in fares than do others, and it is usually to the interest of the railway to reduce fares on these varieties rather than on others less susceptible to stimulation.* The rule that reduced fares call forth increased traffic, whilst in the main true, is subject to limitation. The success of such a policy depends

* "The Passenger Traffic on Railways." W. E. Weyl.

on the existing fare, the density and wealth of the population served, the frequency, convenience, comfort and speed of the service offered, the length of line on which such reduction is operative, and many other factors.

The railways, as such, are not so much interested in the more general economic aspects of the question as in the problem of how far they can develop traffic relatively to their mileage and capital expenditure. The first of these two is a very important question, as bearing not only upon the point of how far the population of a country takes advantage of the facilities for locomotion provided for it, but also upon the further point of how far such facilities are equal to the requirements.*

Where the question of profitableness of a given traffic arises, where it is a question as to whether a certain extension of business will, or will not, pay for itself, a factor is introduced which is usually confounded with that of average cost. This factor is that of marginal or additional net cost. If, after the creation of new traffic, the total receipts of a railway exceed the total expenditure in a greater measure than before such new traffic was secured, then the traffic (factors other than cost being disregarded) is desirable. In other words, if the additional revenue traceable to the new traffic is greater than the additional expense incurred, directly or indirectly, in consequence of this traffic, then the new business is profitable.

The same argument applies to existing passenger traffic. The question is not whether the passenger receipts are greater than passenger expenses (which

* "Railway Problems," p. 233. J. S. Jeans.

are indeterminate), but whether the receipts from this source are greater than the additional expense; than the amount of money that would be saved by cutting off the passenger traffic.

THE SUBURBAN TRAFFIC PROBLEM.

The problem as to how the suburban railway traffic can be effectively dealt with is one that has been of increasing gravity in late years, and now that railways are meeting with such keen competition as that offered by electric trams and motor 'buses in connection with short distance traffic, there has evolved a different phase of operation which, whilst it solves certain difficulties, tends to create others.

The requirements of the suburban service are quite separate and distinct from those previously enumerated. Encouraged by convenient train services, the business man, particularly in London, is now residing well outside the normal suburban zone, and it is, of course, to the interest of the railways to encourage such migration, as it means relatively greater revenue on a steadily increasing traffic which cannot be affected by tram or 'bus competition.

It is essential, when the attempt is made to develop such traffic in new residential districts, that a really good service should be provided at the outset; that it should be in advance of actual requirements rather than that the business should first attain to fairly large dimensions before it is considered necessary to give a good service. This policy is, of course, in complete accord with the railway maxim that "traffic facilities create traffic."

A suburban service must not consist entirely of stopping trains; according to circumstances there

must be through trains each way from and to outlying suburbs. There is a constant demand on the part of the public for the trains which pick up passengers at every station, to be supplemented by express suburban trains from particular stations when there is sufficient traffic to warrant the running of such trains.

The demand for fast trains is one that cannot be disregarded, but as the greatest carrying capacity of a line can only be utilised by running trains all of equal speed, it will be apparent that the introduction of fast trains among trains calling at intermediate stations on a line of high traffic density reduces to a large extent the number of trains which can be worked over a given section of railway; hence the urgent necessity of the provision of special roads for fast trains or accommodation for stopping trains within the suburban areas. This system of duplicating running roads in the special interests of suburban traffic is naturally a most costly one, but with this ever-growing tendency for the suburban area to extend it is difficult to see any other practical method of giving an efficient service when the accommodation on existing roads shall have been taxed to its utmost capacity.

Where the suburban traffic has to be accommodated on one set of metals, however, many measures may be taken to reduce the number of trains running, such measures facilitating to a great extent the running of the fast trains. Assuming that stations are suitably constructed, the first improvement to occur to a logical mind would be the lengthening of trains to the greatest capacity consistent with economical movement, and observation on the main lines running to London shows that this has been carefully studied.

The possible economy can perhaps best be illustrated by the following example. If between 8 and 9 a.m. there are eight stopping trains, each consisting of six "seven-bodied" coaches, and having seating accommodation in each compartment for ten people, the trains would have an aggregate seating capacity for 3,360 passengers. Were the trains reduced by two, and each of the remaining six strengthened by two coaches of similar capacity, there would be accommodation for the same number of passengers, whilst if an equal number of trains were run there would be a seating capacity for 4,480 persons.

Another method of effecting economy is by enlarging the seating capacity of each compartment, and several companies—following the example set many years ago by the Great Eastern—have widened their coaches to permit of seating accommodation for twelve passengers in each compartment, and, in some cases, have widened the first-class coaches, which then have a capacity of eight seats. If we take the eight trains referred to in our previous example (first-class coaches being entirely disregarded), and calculate on this new basis, we find that 4,032 passengers could be conveyed in the same number of coaches, and as this number is 672 in excess of the previous number and the capacity of one train is 504, it is clear that the running of one of the eight trains could be avoided merely by raising the seating capacity of each compartment.

A further most important factor is that arising from the inequalities and fluctuations in the bulk of the traffic. The suburban passenger traffic on the railways in opposite directions balances itself in the

course of a short period, but the traffic is in one direction in one part of the day and in the opposite direction in another, this causing fully utilised stock in one direction and comparatively empty stock in the other. If the mass of traffic were better distributed throughout the day there would be far less difficulty in dealing with it, but the vast majority of the suburban residents desire to reach town in the course of about two or three of the morning hours. To meet this pressure of business, railway companies must provide trains which are, to a great extent, idle during the remainder of the day, the capital represented by them being, during such periods, relatively unremunerative.

In addition, the necessity arises of stabling stock in the immediate neighbourhood of the termini, where accommodation is essentially limited and costly, or of hauling it to sidings removed therefrom and thus incurring extra expense in unremunerative engine-time. A limited service has always to be maintained throughout the day, but there is no demand for the lengthy trains of the business hours, and difficulty again arises, therefore, in the efficient utilisation of existing train-sets.

Strenuous efforts have been made by railway companies to extend the period of operation by means of cheap tickets available during a certain period and before a definite time, and there is no doubt that this practice is a sound economic one. In addition to being advantageous to the railways in the fact that they dispose of some of the traffic earlier than they otherwise would, it has been beneficial to the public, and has contributed in no small measure to the popularity of suburban residence. Moreover, the demand for "luncheon hour" trains has probably

been mainly called into being by this class of passenger, and so serves to enhance the daily utilisation of stock.

Having thus discussed the problem at some length, we may summarise the necessities of an efficient and economical suburban service as :—

(1) Frequent service of trains to and from a given centre.

(2) The greatest possible number of passenger to be carried in each train on each trip.

(3) Suitable schedule times.

(4) Short block sections to expedite running.

(5) Separate roads upon lines of high traffic density for trains which run at high speed and do not stop at all stations.

(6) Prompt departure times from stations.

(7) Powerful locomotives capable of accelerating rapidly and hauling heavy loads.

Suburban traffic, then, to be in the highest degree remunerative, must be handled rapidly, by methods that are simple and inexpensive, and with the minimum working organisation necessary for the purpose.

For the purpose of tapping new sources of passenger traffic, residential or otherwise, and for maintaining branch services, various companies have had recourse to rail motor cars to develop the traffic until such time as it may warrant the running of ordinary trains. The rail motor has indeed justified itself from the traffic point of view in a remarkable degree, and the pages of "Bradshaw" are simply studded with references to motor services, catering in many cases for traffic which has been largely created by the rail motor car. But the need has been better met by adapting old tank engines for use as

motor or auto-trains, there being, even with lined-up cylinders, a wider reserve of power for the attachment of trailer coaches, so that with one engine four bogie vehicles can be conveniently operated. Moreover, the fact that old engines and ordinary vehicles can thus be conveniently used, instead of specially constructed motor cars, has been a controlling factor, while at any time the engine can be detached or used in the ordinary way, for shunting or for other purposes. The possibilities of this form of traction cannot be over-estimated, and due consideration should be given to the various advantages when extended services through sparsely populated districts are proposed.

It is in the direction we have indicated that many of the more difficult aspects of the suburban problem are being solved. Given frequent and punctual services, and fares capable of stimulating this traffic, which, perhaps above all others, possesses the greatest elasticity of demand, the density of traffic will have a constantly increasing tendency, the cost per unit will diminish, and, as a natural corollary, the aggregate receipts will increase in due proportion to the skilful and systematic manipulation of the traffic.

Chapter IV.—GOODS AND MINERAL TRAFFIC.

Services and Rates—Loads, Speeds, Grades and Conditions—Ratio of Effective Work and Margins—Other Considerations—The Business in Small Consignments—Marshalling and Concentration Yards.

Several characteristics distinguish goods from passenger traffic, and whilst certain of these have been previously outlined, others worthy of consideration have not been treated for the reason that they are more closely related to the subject of this article. At the same time, it may appear that one or two of the points discussed in this section have been debated at an earlier stage, but it will be found, on more detailed analysis, that the problems, though generally attributable to the same cause, have varied effects in their relative bearing on the different phases of operation.

SERVICES AND RATES.

The essential difference between passenger and goods services is that whilst the timings of passenger trains have to conform to the requirements of the public, those of goods trains may, generally speaking, be fixed to suit the convenience of the railway. Under British conditions, however, it is necessary for perishable and express goods trains

to run at such times as will enable delivery to be effected early on the day following dispatch, whilst even unimportant merchandise trains cannot be held up, as in Germany, awaiting full loads. The British trader has, in fact, been favoured with regular freight services to such an extent that he now regards it as criminal if his goods are an hour or so late. In this regard we may quote the American writer, Dunn, who, in his admirable book "The American Transportation Question" states: "The fastest and most regular freight transportation in the world is that of England. Consignments of merchandise received at the London freight stations up to 4 p.m. are delivered throughout the country by 9 o'clock next morning."

Such regularity of service is not attained without scientific manipulation of the traffic, and to ensure, as far as possible, the efficiency of operation, very comprehensive regulations and directions are supplied to the staff concerned in train movement. Correlative with efficiency is the necessity for safety. One commonly thinks of safety as of importance only in the passenger service. This is far from true. Railways pay out enormous annual sums for loss of and damage to property, this representing economic waste, a large part of which can be eliminated only by increasing the safety of operation.*

The revenue derived from goods and mineral traffic is, of course, obtained from the different classes of commodities in amounts, relatively large or small, according to the value of the goods and other considerations. The question of rates and operation will be discussed in a later article, but it might here be

* "The American Transportation Problem," p. 128. Dunn.

said that the excursion fares for passenger traffic are paralleled in the special rates for goods traffic, these being put into operation in order to attract traffic which could not bear the ordinary rates. Where the traffic thus secured can be conveyed in rolling stock which otherwise would travel lightly loaded, the additional cost incurred by the railway company is limited to what extra expense there may be in connection with certain terminal services, and very low rates may, therefore, generally furnish sufficient surplus over cost to render the operation profitable. Such rates may be likened to the excursion fares available on ordinary passenger trains. At the same time, the excursion fares introduced in the expectation of attracting sufficient traffic to warrant and earn a profit on the running of a special train have their equal in the low rates accorded to minerals and heavy goods which, carried in small quantities at the highest rates they can bear, will barely cover operating expenses, but carried in large quantities at extremely low rates render operation economical, and result in suitable recompense to the railway company.

LOADS, SPEEDS, GRADES, AND CONDITIONS.

The question of traffic operation is as complex as it is interesting, and its complexity is increased by the varying conditions which prevail on different lines—topography, density of population, nature of industries, production, etc. Whilst this statement applies to passenger traffic as well as to goods traffic, there are several essential differences between the two which render more difficult the elucidation

of the problem in its relation to goods train operation. For example, it is generally true to say that the volume of passenger traffic between any two places balances itself in a given period, whereas, in the transportation of goods the major portion of the traffic is in one direction, and return trains must necessarily run empty, or with diminished loads.

Another fact tending to unfavourably react on goods train operating costs is that passenger trains have a prior right to the use of the road, and the effect of a goods train being "side-tracked" to permit of the passage of its more favoured contemporary is not merely the delay thus immediately caused, but is frequently that period of delay multiplied many times, with consequent unproductive expenditure for wages, coal and water. Thus one arrives at the axiom: Delays are apt to be cumulative.

The loading of goods and mineral trains entails more consideration, and results in greater difference of opinion than that of passenger trains as, owing to the requisite higher standard of loading, greater regard has to be paid to existing gradients and the peculiar requirements of the traffic. For example, there are certain kinds of freight, notably live stock, fresh fruit, and other perishable commodities which particularly require speedy transit and render demands similar to those primarily encountered in connection with the transportation of persons. Between the trains conveying such traffic and those conveying heavy loads of coal a wide difference will be found existent in their requirements for efficient operation.

In connection with passenger train operation, arrangements in advance are largely applicable, but

when goods and mineral trains are introduced, the unavoidable delays which accrue and the variable quantities of the traffic frequently upset preconcerted arrangements, and render necessary deviations from the general lines which may, *inter se,* have a detrimental effect on operation as a whole. One difficulty which immedately presents itself, for instance, is that whilst it is quite exceptional for a passenger train to occupy any section of the line for a longer period than is usual in its running day by day, very little uniformity exists in the case of goods trains, this being largely due to the increase in train loads which are now, in many cases, practically equal to the maximum capacity of the locomotives. As a consequence, when adverse conditions, such as greasy rails, heavy grades, poor coal, bad water, or any slight defect in the engine are encountered, time is invariably lost.

Express goods trains are not, speaking generally, subject to the difficulties inseparable from the consideration of loading in connection with heavy goods and mineral trains. For these trains, merging, as they do, with the "perishable" trains, and often themselves conveying perishable traffic, are not, as a rule, loaded to the same relative hauling capacity of the locomotive, the load being so limited as to ensure, under ordinary working conditions, the maintenance of a fair speed. It is, therefore, in the loading of mineral and ordinary goods trains that the main difficulties, inseparable from the consideration of heavy loading, are encountered, and in discussing the problem of the most economical load for this class of train on any stretch of line, due regard must be paid to the prevailing gradients, the density and class of traffic, the length of block sections, the

existence of goods roads, and the frequency or otherwise of running loops and refuge sidings.

The words " speed " and " haulage " are abstract terms, the first embracing varying distances travelled in a given time, and the second, varying weights hauled for a given distance. The expenses of haulage are, therefore, affected by :—

(1) Varying weights hauled;
(2) Varying distances travelled;
(3) Varying times occupied;

whilst a further element of variation is found in gradients, and certain operating conditions which differ more or less in the case of each railway. There is a decided tendency for the cost of working (considered apart from the weight hauled) to decrease with increasing speed, the greater cost per annum or per trip being more than counterbalanced by the greater mileage.

That speed has a considerable influence on the weight hauled is freely admitted, and it may, therefore, be said that whilst accelerated speed has a tendency to reduce the cost of working per mile, it undoubtedly reduces the capacity to haul, and in any attempt to determine the most economic load and speed it would appear necessary to determine what reduction in weight is equivalent to a given increase in speed, or vice versa. Whilst such a comparison may appear possible, in theory, it would not seem practicable for the railways, with such a variety of demands as they have to satisfy, to determine the practical economic load.

The maximum weight of trains permissible on any given line depends upon a variety of factors—among them being the power of the engines employed, the rate of speed required, and the character of the line

as regard gradients, curves, and the frequency of block posts. The length of available loops and refuge sidings, together with the possibility of the simultaneous fouling of two junctions, have also an immediate bearing on the question of maximum train length. The engine power, speed, gradients and curves are connected quantities. The higher the speed the smaller the load that can be hauled by a given locomotive; and the steeper the gradients and the sharper the curves the smaller the load that the engine can haul, or the lower the speed at which it can travel.*

When one is considering this question in connection with a railway on which special roads are exclusively provided for goods or "slow" traffic, the problem is capable of ready solution. For it is generally admitted that, *ceteris paribus*, the maximum load which an engine can haul up the prevailing gradients may be considered the most economical one under such circumstances, as the trains can all be kept moving. In such cases, it is the usual practice to fix loads which the various engines can haul at 10 miles per hour, and retain that speed on grades of, say, 1 in 100. Higher speeds are, of course, obtained where gradients are less, and where they are heavier, bank engines may be utilised or the trains double-headed.

Attention must also be paid to loading so far as down grades are concerned, as the brake power on goods trains in motion is strictly limited, and special arrangements have to be made so that a sufficiency of brake power may be provided to prevent "running away." This difficulty is overcome by bringing

* "British Railways," p. 171. H. M. Ross.

trains to a stand before they enter on heavy down grades, and pinning down, or "dropping," the wagon hand brakes, the number so pinned varying according to load and grade. In this connection it should be noted that such an operation necessarily creates delay which trains having sufficient brake power do not suffer; as a consequence, the latter clear the section with greater celerity.

On lines not specially provided for goods trains the most economical load—especially where the roads have a high traffic density—is probably something less than the load defined above, owing to the fact that strictly limited time intervals are available for the passage of such trains. The economical size of load is directly affected by the time occupied by the engine in hauling it from one block section to another, or from loop to loop. Above a certain point, the heavier the load the longer will it take to haul and the more often arises the likelihood of the train being delayed awaiting a suitable and sufficiently long time interval.

The duration and recurrence of time intervals may be said to vary according to the period of the day, and even according to the season of the year. At night, for instance, over certain stretches of line, long time intervals may prevail, thus affording facilities for the passage of heavy goods and coal trains, whilst, during the day, short intervals may be the rule, and then the lighter and faster trains have the advantage.

The problem, therefore, which faces the traffic operator is whether, over any given stretch of line, it is more economical to work, say, fifty trains of fifty wagons each, or sixty-two trains of forty wagons each, and experience alone can enable a

justifiable decision to be formed. It is all very well, in theory, to establish an arbitrary decision, based on some comparison (probably of varying quantities) as to speed, loading, etc., but in practice it is only possible to effect suitable economies after experiments based on a general observation of the existing conditions and special circumstances in each particular instance.

RATIO OF EFFECTIVE WORK—AND MARGINS.

A factor very closely related to the loading of goods trains, and one that requires careful consideration in connection therewith, is the ratio of running time to standing time, or, in other words, the ratio of effective to ineffective work. For the greater the effective work the cheaper is the cost of transportation, and the greater the time standing the heavier the cost of transportation.

The considerations involved differ essentially from those present in the case of passenger trains, where but one important factor—the intervals between arrival and departure—enters into the subject. Certain interdependent factors affect both standing time and effective work. Thus heavy loading, in all probability, increases standing time, and to increase the effective work the engine loads must, in many cases, be decreased, though to what extent economically it is practically impossible to determine owing to many other varying conditions, such as density of traffic, length of sections, and proximity of loops and refuge sidings.

This ineffective work arises from a variety of causes, including detention at signals on running lines, detention in loops and sidings awaiting work-

ing margins to permit of passage to the section ahead, backing into sidings, where not only is time wasted but also steam and coal in retracing the distance once covered and again in passing over it when departing. An important feature, therefore, of the operation of lines of high traffic density is the occupation of the line. How loads will affect this is well illustrated by the following example.

If a train of 60 wagons occupies 30 minutes in running from the exit from loop A to the entrance to loop B, and one of 45 wagons 20 minutes, then in the first case the time occupied per wagon is $\frac{30}{60}$ = .5 minutes (i) and in the second case $\frac{20}{45}$ = .4 minutes (ii). The time occupied by 90 wagons would, therefore, be in the first case $\frac{30 \times 90}{60}$ = 45 minutes (i), and in the second case $\frac{20 \times 90}{45}$ = 40 minutes (ii). From this it is clear that in the latter case a greater quantity of traffic will pass over the road in a given time, and, owing to the smaller requisite working margins and the resultant more numerous opportunities for preceding more important trains, a greater mileage per engine hour will accrue.

The utilisation of bank engines to assist trains up heavy gradients has of late years become an established method of operation, and although with such engines the ratio of effective work is comparatively small, they are no doubt economical, as not only may heavier loads be conveyed on through trains for which one engine is ample for 90 per cent. of the journey, but time is saved in through trains making up loads at the summits of gradients.

One other feature requires special mention at this point. There is an outstanding difficulty in the establishment of a unit for use and comparison in

connection with train loading. The unit most generally adopted is the wagon. This may be of 8, 10, or 12 tons capacity, and may contain weights varying from a few hundredweights in the case of certain goods traffic to the full capacity of the truck in the case of other traffic. Accepting the wagon as the unit, then, there might be a train of 50 wagons, each having a tare of 6 tons and a load of 4 tons, representing a total weight of 500 tons, and another train of 50 wagons, each with a tare of 5 tons and a load of 2 tons, representing a total weight of 350 tons. In connection with mineral traffic the objection to taking the wagon as a unit is intensified for the reason that a train may consist of 30 8-ton wagons or 30 12-ton wagons each loaded to their full capacity. Thus one train would contain 240 tons and the other 360 tons, though both were loaded on the same basis.

In practice the wagons would, of course, be more generally mixed, but the illustration serves to show that the generally adopted unit may not be used as a calculable factor in any true analysis of train loading. It further serves to indicate that different trains, though loaded on the same unit, necessarily occupy a section for varying periods, and it is the unit which, to a great extent, creates (indirectly it is true) the difficulties caused by trains taking more than average times to cover a section.

In connection with the fine timing of passenger trains, and the considerable importance attached (probably rightly) to their punctual working, there is a tendency on the part of the signalman to overestimate such importance, and to detain goods and coal trains in loops and sidings, although there may be a fair and workable time interval to allow of their

passage to the next loop or shunting refuge without probable risk of delay to a following passenger train. Indeed, experience has shown that if a signalman should permit a goods train to leave his section with a margin of 18 minutes, and owing to unforeseen and special circumstances, delay should result to a following and more important train, he will thereafter allow no such train to leave his section without an available interval of 19 or 20 minutes, although, in reality, and given fair and ordinary working conditions, a 16 minutes' margin is all that is necessary. Such a course would be particularly undesirable if the suggested policy of modified passenger train timing be adopted.

On the other hand, admittedly, too great a responsibility appears to be placed upon the signalman when it devolves upon him to fix working margins, and it seems but right that the driver should also have certain responsibilities in the matter. In fact, there would appear to be a call for official marginal timings, providing always that the conditions governing the road are such as to render them workable and desirable. In such manner will the traffic officer, as the responsible head of the district, be vested with the power of deciding what is and what is not a workable margin, and such particulars will at all times be available to the signalman as his authority for action, the driver being then also subject to his full and proper mead of responsibility. Such instructions should, of course, be elastic enough to permit of qualification by the local official to meet peculiar circumstances.

As an alternative, or as an adjunct, to this condition, the actual control of the working of trains by a central authority has recently been inaugurated

on some lines, and thus the signalman has been divested of a large share of responsibility, his actions, in doubtful cases, being subject to the authority of the central control. Moreover, this system has been found to have beneficial effect in the reduction of standing time, consequent on a central authority being kept advised of the passage of all trains over the given stretch of line, and thus being in a position to take necessary steps for the relief of congestion, either by putting back or cancelling certain trains or lengthening others, the maximum possible utility of engine power thus being gained.

For the maintenance of efficient operation, it is essential that the signalmen should, in a large number of cases, have due notice of the approach of particular trains and, in all cases, be able to converse freely with the boxes on either side. For this purpose, the majority of the railways have elaborate installations of telephone circuits. A signalman may, therefore, ascertain the length of an approaching goods or mineral train, and make what arrangements the particular circumstances may justify; either to shunt it or to pass it on to the section ahead. In this connection useful data as to the standage capacity of loops and refuge sidings are issued by some companies to their staffs.

Newly-constructed refuge sidings or loops should be of such capacity as to accommodate trains of maximum conceivable length. The considerable increase in loads of latter years and the resultant incapacity of previously existing refuge sidings and loops have resulted in considerable delays—delays which it is essentially difficult to remedy, in a large number of cases, owing to the impracticability of lengthening or widening.

OTHER CONSIDERATIONS.

It may be possible, in some instances, to increase the efficiency of operation by scientific analysis of the traffic density, though extreme care is necessary if an accurate solution of the problem is to be formulated. In calculating the maximum density of a stretch of line for economical operation, it must be remembered that conditions vary, and that the best conditions, or even the average conditions, cannot always be taken as a sound basis.

Weather has a potent effect on railway operation. Generally speaking, conditions are much more difficult in winter than in summer, though there is a compensating factor on most lines in the smaller number of passenger trains during the winter months, which reduces the necessity for the quick passage of mineral trains. Fog, prevalent as it is in some districts, has a disastrous effect on train working, but it must be regarded as an extraordinary feature, and met by extraordinary measures.

It would certainly appear economical, though it may not be the general practice, to cancel all slow moving and unimportant trains at the commencement of a thick fog and leave the road comparatively clear for passenger and express goods trains. Engines, immediately on fog clearing, may then be brought out of shed, and though "block" is undoubtedly created by the accumulations at collieries, etc., trains may be worked, whereas if "block" occurs during fog (as it frequently does), trains are standing in every siding, and it is invariably found when the weather clears that there is a shortage of power and enginemen owing to their having been standing on duty instead of resting.

A further point, which might be elaborated, is the waste of fuel in this latter circumstance. Steam has to be maintained, and coal, therefore, used ineffectively. The sum total of "coal used but no effective work performed" would amount to no mean sum in a year

THE BUSINESS IN SMALL CONSIGNMENTS.

The trade of the country is essentially retail, and therefore demands the quick and prompt delivery of merchandise despatched by goods trains. The necessity further arises not only for the quick transportation of goods between important towns where the quantity is such as to make full wagon loads, but also for the prompt arrival of odd packages at the various smaller towns and villages, the goods for which do not warrant the running of through wagons.

As far as it can reasonably be done, it is no doubt to general advantage to get a full load from the station of origin to the station of destination in one transit. Where this cannot be effected, the almost uniform practice of railways in England is to load a wagon of goods to an intermediate point on the route, to be there unloaded and re-distributed, such consignments being termed "tranships." To help in this process, a very elaborate system of what are technically known as "road" wagons has been developed, the central points of the road wagon services being, as a rule, the large goods depots, which, in this matter, act as transhipping stations.

These wagons are conveyed by stopping goods trains and the goods for each station taken out while the train stands at the platform; in some cases, the

wagon is detached and taken forward by a later train. It is not, of course, possible to arrange such facilities between all towns and villages, and many such goods are loaded to a centre near the destination, whence either a through wagon or a road wagon can be forwarded. Both methods of operation are somewhat expensive, and no extra payment is made by the public for the extra service, except in the form of a slight additional payment of all small consignments not exceeding 3 cwt.

It is necessarily impossible, in the majority of cases, to fully load road wagons, as, if this were done, the unloading could not be accomplished with rapidity. The loading is very expensive, for the goods to be forwarded per road van must be assembled before a single package is loaded, so that they may be so placed in the wagon that the goods for the first stopping place are nearest the door, those for the second stopping place next, and so on. A further disadvantageous feature is the considerable time occupied in the unloading at the stations and the occupation of the main lines during (probably) busy times of the day.

It is, therefore, questionable whether it would not be more economical to convey all such traffic—especially on branch lines—on certain early morning or late evening stopping passenger trains easily timed to provide for the extra time occupied in unloading, although the time so spent would, or should not be, so great as under the road wagon system, as the guard could, *en route,* get the different packages ready for discharging immediately the train stopped. In this connection, consideration must be given to the fact that such arrangements might have the effect of diverting

some traffic now conveyed by passenger trains at relatively high rates to the goods service, and it may further be urged that there would be a disadvantage in the intermingling of goods and parcels traffic, with possible complications.

It would, nevertheless, appear desirable that experiments should be made in the endeavour to avoid road van work by concentrating the consignments at particular stations, the passenger trains affording a means of effecting this. That passenger trains could perform this work without undue inconvenience appears highly probable. The limit of weight and bulk is broadly the limit of easy handling, and it would appear that packages which can be easily handled by a pick-up goods train could be easily handled by the staff in charge of a slow or branch passenger train, and would not mean delay to the passenger traffic, as the conveyance might be spread over a number of passenger trains.

MARSHALLING AND CONCENTRATION YARDS.

In considering operation, one must not overlook the marshalling of trains, a duty performed either at the point of origin of the traffic or at some central yard laid out for that purpose. But few yards where business originates possess, or would it be practicable to provide at them, suitable means of marshalling a large number of wagons, as, in addition to the high cost of land, there is the important fact that railways form such a network that junctions occurring every few miles render it but seldom possible (in the case of ordinary traffic—as distinguished from export, import and mineral) to

dispatch through trains fully loaded from any originating point to one destination.

Were all traffic to pass due north and south or east and west, this formation of trains would be a simple matter, but as a result of the proximity of industrial centres and the many converging lines connected therewith, it would be necessary, if sorting sidings were not provided, for trains to detach and attach wagons at many intermediate points, a procedure which would result in chaos under present-day conditions. It would, therefore, appear that the central marshalling sidings and concentration yards are of great utility, as they enable distinct economies to be effected in operation by the aggregation of the various units of traffic.

Marshalling and concentration yards may be said to fulfil the same object, viz., the reception of "rough shunted" trains and their sorting and marshalling into train and station order. The existence of such yards enables the operation of marshalling to be transferred from the originating point of the traffic to an easily accessible centre located as near as possible to the direct line of route over which the traffic should pass. This centralisation of operation, as we may term it, results directly in the concentration of shunting staff and accommodation, both of which factors are economical, inasmuch as the staff requisite for dealing with a given number of wagons at one spot is necessarily smaller than that required for dealing with a similar number at separate places; and so with the accommodation, this being less expensive per acre in so far as those yards located in country districts are concerned. Further, the concentration of accommodation ensures maximum utility with a minimum of unproductive capital.

Another factor in the economical utility of marshalling yards is their capacity to act as connecting centres for freight trains, just as junction passenger stations afford connecting points for passenger trains, a factor alone leading to considerable economy in engine hours; in addition, traffic for wayside stations can be put off the through goods trains at the yards, to be conveyed therefrom by the daily "pick-ups"; and so, in the reverse direction, can odd wagons from small stations be concentrated on the yards. Exchange of traffic can, therefore, be effected with a minimum of standing time or ineffective work, particularly in view of the fact that in the construction of sidings for sorting purposes their design may be such as to enable the work of marshalling to be performed in the most economical manner.

Thus far we have dealt with goods, but like conditions prevail as regards the mineral traffic which is concentrated from the collieries to the yards, this resulting in the formation of through maximum train loads to ports and consuming centres.

Marshalling yards may be classified as under :—

1. Engine worked yards.
2. Gravity yards.
3. Partial gravity yards.

All three should have the main features of reception and departure roads clear of the main line, and of groups of sorting sidings located between them. Yards under the first category are worked entirely by engine, with the help, perhaps, of a slightly falling gradient. In this type of yard, therefore, the number of wagons dealt with per engine hour will be the smallest when compared with the yards comprised under the other two categories. Gravity

yards provide for the work of shunting to be performed entirely without the help of engine power. Here the fall has to be considerable, and the ground must be naturally adapted for the gradient. In partial-gravity yards, part only of the work is done by engine power, which has to be utilised to propel the wagons over a hump, the fall on the opposite side serving to gravitate the wagons into the various sidings.

The tendency of late years has been to construct gravity sidings where conditions allow, and partial-gravity yards where the outlet of the departure roads has, of necessity, to be in approximate alignment with the inlet to the reception roads. In both these types of yard, the utilisation of gravity necessitates the employment of increased staff to cope with the faster moving vehicles, but this expense is more than counterbalanced by the considerable economy in engine power. The working capacity of such yards depends, to a great extent, on the degree of the gradient, and whilst the necessity for manual labour would be less if the gradients were easier, such a condition would impair the efficiency of the yard, this being measured by the amount of traffic which may be dealt with in a given time. It is necessary, therefore, to provide grades suitable to the maximum requirements, always, of course, within the limits of easy running.

Suitability of construction is essential. Ample reception roads are necessary to avoid holding trains back on the main lines, and the number of sidings —the points for which may be centrally controlled —must be commensurate as far as possible with the different main destinations of the traffic : otherwise, considerable shunting may be rendered necessary at

the departure end—a result obviously undesirable. Wherever possible, "up" and "down" traffic should be entirely separated, and, generally speaking, the most efficient operation of both yards and running roads is obtained when the main lines or goods roads pass between the sets of sidings, as this obviates the necessity of trains having to cross the running roads when entering or leaving the yard.

The economical size of the yard is necessarily that which will enable it to deal with the greatest amount of traffic offered to it, under ordinary working conditions, and regard must be had to the fact that the sidings must not only have accommodation for the sorting of the traffic conveyed by a certain number of trains, but must also have available room for the standage of wagons awaiting handling or necessary connections. At the time of construction it is obviously impossible, owing to never-ceasing fluctuations, to determine the quantity of traffic which will require to use the yard, and whilst every consideration must be paid to estimated existing requirements, the possibilities of future enlargements must also be borne in mind in order that any additional accommodation may be provided with a minimum of expense.

The economical operation of marshalling yards is largely dependent upon a continual flow of traffic. In the engine-worked and partial-gravity yards it is necessary that the engines should be constantly employed; in all three it is essential that the staff on duty should be fully occupied. In this connection, the close relationship to and bearing of yard operation on line operation must not be overlooked. If the operation of the line is impeded, if block of traffic and congestion arises, not only is there an

immediate loss in trainmen's wages and in the effective work of the locomotives held up, but the whole work of the yard is retarded. Inspectors, shunters, signalmen are all idle; shunting pilots are standing, and traffic in the yard awaiting connections is being delayed. When the congestion on the line is removed there is a rush of traffic to the yard such as cannot economically be handled, and again are the trains delayed in the reception roads. At the same time, re-formed trains are leaving the yard at too frequent intervals, and blocking the main lines and other concentration yards at other parts of the system.

The interdependence of the operation of running lines and concentration yards cannot be too strongly emphasised, as, unless the theory of the subject be thoroughly studied, there is a natural tendency for the yardmaster to relieve the congestion of his yard at the expense of the running lines, though, economically, each should bear its fair share of the "block," and thus ensure the most effective operation of trains under the exceptional conditions.

Chapter V.—TERMINAL OPERATION.

The Passenger Station—The Goods Depot—Cartage—Tranships—The Proposed Goods Clearing House.

In logical sequence to the papers on passenger, goods and mineral traffic is the consideration of terminal operation, the most important factors in connection with which are the formation and lay-out of the accommodation. The celerity with which work at terminals can be conducted is, in fact, one of the essentials to efficient operation, and it will be well, therefore, in view of the varied conditions under which this work is performed, to discuss the requirements in the light of principle.

THE PASSENGER STATION.

The essentials of an ideal passenger station are long platforms and a good circulating area. Many other features, however, enter into constructional considerations, and these have a great effect on operation. From the point of view of terminal operation *per se*, probably the most economical type of intermediate or roadside station is the "island" which permits of one, and only one, means of ingress and egress for pedestrians, and thereby reduces the possibility of passengers entering and leaving without possessing tickets or paying their fares; it also enables staff to readily transfer their attention from

up to down trains or vice versa, and at junction stations obviates the necessity of transferring parcels etc., traffic from one platform to another in addition to promoting the concentration of supervision. A further advantage of the island platform is that it lends itself more readily to widenings of the line, and thus avoids certain expenditure when subsequent extensions may be necessary.

Objections to this type of station do, however, exist in the fact that parcels traffic and luggage originating in or destined for the district served must, of necessity, be carried up or down stairs, except at stations where the volume of traffic warrants the provision of lifts. A more serious objection is the effect on the alignment of the permanent way, the necessary reverse curves tending adversely to affect the running of express trains. Moreover, the economies obtained in the requirements of staff must not be over-estimated as, generally speaking, on but few occasions do two trains occupy the average station at the same time, and the possible reduction of staff as a sequence of the single platform does not amount to any tangible figure. Nevertheless, the constructional costs of the island station are considerably less than those of the double-platform type, where not only are two platforms necessary, but also, probably, two sets of buildings and a footbridge or subway.

In connection with roadside and intermediate stations it is but obvious that due consideration should be given to the question as to whether solidity and permanency of initial construction is desirable, as, owing to the ever changing and progressive phases of modern conditions, due regard must always be had to the possible necessity for

widening the line or possible decay of traffic owing to tramway or other competition, or other diverse circumstances. Where it is not apparent that there will be a sufficient flow of traffic to warrant the construction of the ordinary type of station it would appear advisable to make a "halt," which could, as desirable, be supplemented with the necessary facilities.

The question of free public access to all station platforms is a somewhat peculiar one, owing to the inherent idea that railway stations are public places. No doubt it would be unwise for any one company to commence altering existing conditions at all stations on their line, but it is difficult to understand why universal action should not be taken, as experience shows that existing facilities afford opportunities for considerable abuse, inasmuch as passengers between country stations, where the check on tickets is not severe, may in many cases pass as non-travellers, and so avoid payment of the fares for which they are liable. At large stations, a check on persons using platforms is essential, unless the "trains" are collected or examined at a preceding stopping place. This practice is observed at the approaches to certain stations, in some cases special ticket collecting platforms having been erected within a few hundred yards of the station—a somewhat extravagant procedure, although the check, particularly as to the class of carriage occupied, is necessarily a most complete one.

Nowadays, the closed station method is generally adopted, and this is gradually being extended in spite of the superficial objections of the public. The advantages of the closed station are twofold, viz., economy in ticket collecting staff and avoidance of

delays, for, except on extraordinary occasions, it obviously requires a smaller number of men to collect the tickets from one train at a barrier than if it were standing at a platform, whilst, in addition, there is the possibility of collecting two and even more " trains " simultaneously. Likewise, there is an avoidance of delay owing to the time otherwise spent at a ticket collecting station being obviated. At such stations there is also a check on " outward " passengers, whom it is thus possible to confine to the circulating area, and admit to the platform at times most convenient to the operating staff, overcrowding of platforms during train movements in this way being avoided. This practice, though frequently adopted on the Continent, is not general in this country except at termini. Platform tickets are issued to persons using the platform and not desiring to travel, and there is now a tendency to adopt the Continental practice of charging therefor, which is reallv but logical when it is considered that railway companies have serious responsibilities in connection with persons using their stations, whether for the purpose of travelling or not.

Apart from the construction of station buildings, the lay-out is a most important matter, particularly at stations where any amount of attaching to or detaching from passenger trains is necessary and the traffic does not warrant the retention of a pilot engine. Reference has been made to this point in connection with passenger traffic operation, but it must be regarded also in the light of terminal operation. It is obviously impossible to so locate the carriage dock that an engine may set back directly on to it from both directions, but if the small distance between the common line and the

end of the dock be absolutely level, manual labour can perform all that is necessary in transferring trucks to a point directly accessible from both up and down roads.

The actual revenue derived from passenger trains is in respect of conveyance only, no terminal charges being included in the fares charged, and the passenger station may, therefore, in one sense be regarded merely as a collecting centre for the moneys due for conveyance, in addition to a point of concentration and distribution for passengers. Probably one of the most important phases of station operation is the collection of tickets and excess fares. There is a tendency towards laxity in this respect owing to the fear of offending passengers. Such a feeling, however, is surely devoid of perspective, for if all the railways comprised in a certain district or country would unanimously insist on passengers exhibiting their tickets on every occasion that they enter or leave the station, a substantial increase in revenue would accrue, as there is no doubt that, under the generally existing haphazard arrangements, railway companies lose considerable revenue.

THE GOODS DEPOT.

The main difference between passenger and goods terminal operation is found in the fact that the movement of persons is self-directive or voluntary, and there is, therefore, no necessity of loading and unloading on the part of the railway company. Further, parcels, etc. (apart from horses and carriages), conveyed by passenger train, and consisting, as they do, of light packages, do not require any special methods or appliances for handling. General

goods traffic, on the other hand, requires considerable service and attention at the terminal points.

The constructional features and lay-out of a goods station determine, to a large extent, its economy of operation, and although local conditions may vary considerably, goods depots may be expressed as capable of classification under three distinct categories which, however, under certain circumstances, merge one with the other.

First, there is the country station, which should have one or two sidings and possibly a covered platform for unloading and storing on the same level.

Then, for towns of moderate size, somewhat better accommodation is necessary, and there should be several sidings and suitable cranes, as also a shed, preferably with a second floor for storage purposes, and the necessary hand-gear to facilitate hoisting.

Thirdly, the large town or city station should be provided with numerous sidings, a crane of from 25 to 50 tons capacity, one or more yard cranes, a commodious shed and warehouse capable of storing several thousand tons of goods, hydraulic or electric power for operating cranes, lifts and jiggers, whilst hydraulic capstans and turntables or traversers may be furnished for the transference of wagons, loaded or empty, from one road to another.

The volume of traffic using the first type of station—limited, as it is, by the consuming and producing capacity of the area served—does not usually warrant the installation of handling equipment, the manual labour of the station porter being all that is necessary to perform the railway company's share of the work; in fact, the traffic actually handled by the railway staff at such stations may be almost

a negligible quantity owing to the preponderance of "S to S" traffic in full wagon loads, light goods (with the exception of a few consignments conveyed in the road vans) being carried by passenger train.

In the second class of station the conditions deviate between those appertaining at the first and third, a small staff having to be maintained to load and unload wagons and drays, the latter being provided by the railway company or through a carting agent. The principal consideration at such places is the lay-out, the most important item of which is the necessity for the provision of shunting necks to enable all shunting and marshalling to be performed without utilising the main lines and thereby interfering with the operation of through trains; causing shunting to be abandoned; or, on the other hand, the discontinuation of shunting while through trains are approaching and passing.

The third class of station represents the type at which well-considered construction and appliances are most essential. The traffic is large in volume, and, being concentrated, power-actuated machinery may be introduced to assist or replace manual labour. For a low capital cost coupled with ill-devised equipment and a consequent high labourage bill may be less economical than a high initial capital cost in construction and first-class equipment. As regards existing goods stations, situated necessarily in the midst of large towns and cities, extension of accommodation to meet the increased demands of a growing traffic is essentially costly, and at times even impossible. In such cases, a well-considered improvement in and extension of handling and moving appliances may go far to remedy the deficiency; may, in fact, put the depot concerned on a line with one

of adequate accommodation but inferior equipment. Thus, the provision of suitable cranes on shed platforms may render possible the unloading of a greater number of wagons per hour; the provision of a travelling overhead crane may effect a reduction in the number of wagons requiring standage room; and suitable lay-out may permit of rapid marshalling, this enabling termination of loading to more nearly approach train departure times.

It is obviously uneconomic to allow wagons to remain under load when the demand for them exceeds the supply, granted always that the earning capacity of a wagon is greater than the cost of unloading and storing its contents (i.e., when payment is not made to the railway company for detention). It is also uneconomic when the standage accommodation is so limited as to necessitate extensions or additional shunting, the cost of either being understood to exceed the cost of unloading and storing. These facts have necessarily to be considered when deciding whether it be advisable to discharge wagons rather than to allow them to remain under load, either in private sidings or at terminal depots.

The most important item of expenditure in connection with the operation of a goods depot is that of wages, and the most economical utilisation of labour is, therefore, essential for efficiency. Economy is not always obtained by the employment of a small staff, and, conversely, a large staff does not necessarily ensure efficiency in operation. This being so, it is necessary for the person responsible for station management to keep constantly in touch with the conditions in order that he may increase or decrease the staff in accordance with the requirements. It is probably advisable, at stations of any

size, to employ an amount of casual labour which may " stand off " at a day's notice when business is slack. To this class of labour there are certain objections, but it is difficult to see how the troubles consequent on the fluctuations of business are to be otherwise nullified, and as, generally speaking, there are numerous spheres of terminal work in which men who have more muscle than experience can be suitably employed, the introduction of such labour would appear warrantable.

The staff at a goods station may be divided into productive and unproductive classes, though each of these classes does, at times, merge with the other. The productive consists of staff directly employed in the loading and unloading of goods; the unproductive of shunters, number-takers, timekeepers, warehousemen, etc., etc., whilst foremen, checkers and cranemen may be regarded in this class to some extent. The unproductive staff cannot fluctuate in the same ratio as the traffic owing to the reduction or increase in the business being, up to a point, insufficient per man to warrant more or less foremen or shunters, but this does not allow of any less attention on the part of the agent as a point is reached, sooner or later, when re-arrangement of such staff may warrant reduction or save increase; or, on the other hand, render increase economical. To a great extent, however, the productive staff may fluctuate with the traffic (though this must be qualified in the fact that less traffic does not necessarily entail the use of a smaller number of wagons), and to effect economy, a separate record of the expenditure on such staff should be compared with traffic figures daily and weekly.

The efficient arrangement of the work of unpro-

ductive labour is necessarily controlled by local circumstances, and to these no general rules are possible of application, except in so far that no man should be given so much work that, as a result of his being in arrears, the time of other men is wasted. To ensure that he has not too little work is an essential of organisation. The efficient employment of the productive staff is a matter of organisation, and largely dependent on the proper performance of their duties by the unproductive staff, and the suitable division into gangs for the work at hand. The useful number of men per gang varies with local conditions, the class of traffic, the arrangement of the shed and the distance goods require trucking. Assuming the use of one loader or unloader and one checker, sufficient truckers should be provided to keep these men going, but not so many that the loader cannot keep pace with the goods brought to him, or, in the case of discharging, that truckers are waiting for loads.

As an incentive to smart loading and unloading, a bonus system has been adopted at many places whereby men are paid according to the quantity of goods handled. There is no doubt that this operates for quicker work, but the advantages should not be over-estimated, as possible damage, resulting from rough handling, bad loading, and light loading must be taken into consideration. Such disadvantages may, of course, be overcome by capable supervision and careful selection of loaders and checkers, in the same way that good foremen under the "payment per hour" system will operate for smarter work. In fact, the selection of capable foremen is a most important matter. However capable an agent may be, he cannot attend personally to all phases of the

work, and he should, therefore, select from the staff some "born leader of men," and not, as Mr. West puts it, in his book, "The Railway Goods Station," a man too far gone in serving to acquire the mental strength of a supervisor. In reference to this point Mr. West further states: "When a man has been a manual worker for many years he frequently becomes so used to being led without thinking for himself that he is too mechanical in his ideas to direct and command others. An encouraging eye, therefore, should be kept on all promising young men as possible understudies to the foremen."

Perhaps another point worthy of mention in connection with the terminal staff is the necessity for the concentration under one head of the whole of the staff at a goods station. It is the practice on some lines to have the traffic staff, yard inspectors, shunters, etc., directly responsible to the traffic superintendent, but this has a tendency to create departmental friction and possible loss.

The cost of handling at a goods depot is immediately affected by the operation of the goods shed. There must be an organised system not only for the loading and unloading of goods, but also for the grouping of those taken from the wagons in such a manner as to avoid unnecessary handling in connection with the loading up of the drays destined for the various individual districts covered. Different spaces on the platforms must, therefore, be allocated for the placing of goods for each district, the dray for any particular "round" or district being drawn up alongside such space to enable speedy transfer from stage to dray. Both for this purpose and to meet the requirements in connection with the nightly loading up and dispatch of goods,

the cart road through the shed should be of ample width to allow of drays passing one another whilst others are standing at the platforms. The necessity for this is particularly evidenced at night, when the drays pour into the shed and require, as far as possible, to draw up at the platforms adjacent to the wagon or wagons destined for the stations to which their loads are consigned. Ample width of platforms is also essential to facilitate rapid barrowing from dray to wagon and vice versa, and to allow of the standage of transhipped consignments without interference with ordinary operation.

The distribution of labour, or, in other words, the size of the gangs, directly affects the cost of operation, and in this connection the point of true economy can only be found by close observation and consideration of peculiar and local conditions. In comparing the cost of handling at two or more stations, regard must primarily be had to the average weight of each item of traffic, to the proportion of tranships passing over the stage, and to the amount of handling performed by the cartage staff. In the first case, the smaller the average weight per consignment the greater the cost of handling per ton; in the second, the larger the proportion of tranships the greater the cost of handling per ton of traffic passing through the depots, as all tranships must be handled twice (i.e., unloaded from wagon and loaded up again) in addition to necessitating sorting, and barrowing over the stage; in the third case, the larger the amount of handling performed by carters in loading up goods from stage on to drays, the lower will be the cost of handling *per se,* and the higher will appear the cost of cartage.

Further, it is well to consider the various sections

into which the traffic dealt with at a goods station may be divided. They may be as under :—

(1) Miscellaneous goods passing over the stage, consisting of C and D traffic.
(2) Heavy goods passing over the stage, requiring the use of cranes (usually C and D traffic).
(3) Through loads of goods not requiring the use of crane—dealt with in yard and loaded direct from wagon to dray—C and D traffic.
(4) Through loads of goods not requiring the use of crane—dealt with in yard and loaded direct from wagon to dray—S to S traffic.
(5) Through loads of goods dealt with in the yard —requiring the use of crane—usually S to S traffic.
(6) Heavy traffic requiring the use of high capacity cranes.
(7) Live stock, loaded and unloaded at special dock.

The costs of operation in connection with these different classes of traffic vary considerably, and in endeavouring to arrive at the maximum point of economy they must each be considered separately; otherwise, a preponderance of one class might give a relatively false high or low cost of handling. The first-mentioned class of traffic requires the most constant attention, as, if reasonable accommodation is provided for the others, it is in such cases a simple matter to increase or decrease the staff in accordance with the flow of traffic. In traffic dealt with across the stage, however, fluctuations cannot always be met by a proportionate increase or decrease in labour because the major portion of the handling is limited at most stations to a few early morning and evening hours.

Of the traffic mentioned, a portion requires warehousing, as the British railway companies, unlike their foreign contemporaries, undertake this work and give free warehousing for periods varying in different districts in accordance with local conditions. To effect economy this portion of the work must necessarily be considered separately. The most essential point, however, is that double handling should be avoided wherever possible, and goods hoisted direct from wagon into warehouse and the wagons promptly released.

The sorting of incoming wagons into groups, viz. :—

(1) Sundry, destined for the shed,
(2) Full loads for storing in the warehouse,
(3) Full loads for the yard,
(4) Full loads for yard crane,
(5) Full loads for high capacity crane,

is obviously necessary, and where, through insufficient data on wagon labels, etc., wagons are wrongly grouped, additional shunting and possible inconvenience during the course of same accrues. The full loads should receive attention as circumstances and conditions allow, but sundry goods amongst which is contained the most urgent traffic, should be promptly placed on the shed roads.

Whereas with passenger traffic the haulage charges are the determining feature in the fare, no charge being made for terminals, with goods traffic the terminals are a considerable factor in the rate, covering, as they do, the provision of terminal accommodation, sheeting and unsheeting the wagon, handling the traffic, warehousing and carting, the conveyance, of course, terminating when once the wagon has arrived at the station.

As with marshalling yards, the relationship between the operation on the line and at the goods depot is a most important one. For the punctual departure of the train from the depot depends upon the traffic being ready for the train, and this is only possible if the operations of delivering the goods to the shed or truck, loading, sheeting, labelling, and shunting are performed promptly.

CARTAGE.

Like many other of the important motive powers used in the transport business, the economic utilisation of horses and drays or motor lorries lies, to a large extent, in the ratio of effective to ineffective work. If it were possible to have teams continually hauling loads either to or from a station, probably motor lorries would ere this have superseded the horse-drawn vehicle, but such a proportion of the day's work consists of loading and unloading at the station and discharging or loading up at warehouses that the inordinate percentage of standing time renders the efficient use. of power-actuated vehicles of high capital cost questionable.

To effect any reduction in operating cost it is necessary to reduce the periods of standing time to a minimum, but this can only be done by a surplus of drays which may be loaded by men other than those in charge of the teams. This idea cannot, however, be adopted to any great extent in the loading of sundry goods except by men who know equally as well as the carter the district for which the goods are destined; otherwise, the saving effected may be nullified by the delays at the consignees' warehouses in sorting out the load to get at the par-

ticular consignments; whilst such sorting, where the load consists of heavy packages, may be impossible by one man.

TRANSHIPS.

Economic transportation demands the greatest possible proportion of paying weight conveyed in rolling stock as compared with dead weight, a feature which involves the suitable construction of rolling stock. In addition to this point—which will be discussed in a later paper—there is a co-factor in the loading of wagons to their full cubical capacity. This is, perhaps, not a difficult matter in the case of heavy traffic and large consignments, but in regard to small consignments, of which such a large proportion of the trade of this country consists, it is by no means easy of arrangement.

The quicker the transit afforded, the greater the likelihood of obtaining increased volumes of traffic between the points concerned, and the greater the encouragement to trade in the spheres covered. Whilst between the larger towns and cities sufficient traffic usually presents itself to enable reasonable utilisation of stock, the aggregation of small consignments from the larger producing centres to small towns, and between small towns, seldom warrants the running of individual wagons, and it is necessary, therefore, as mentioned previously, to utilise road vans, or send to a point short of destination for transhipment.

Several railways have constructed stations specially for dealing with such traffic in places where land is not expensive, whereas other companies deal with tranships at their town goods stations along with the traffic destined for or dis-

patched from the particular town. Under the tranship station scheme, an endeavour is made to unload goods arriving by one train and to sort, reload according to destination, and dispatch by a train leaving within a few hours, but to a large extent their success is dependent on the physical features of the line, as will be indicated.

The outstanding advantage of the utilisation of the ordinary city goods depot as a transhipping point is that goods despatched from a given station for delivery in the city plus tranships may provide a full load, but, without tranships, might entail a lightly loaded wagon, or even fail to warrant the running of a separate wagon, all the goods then having to be despatched to the separate transhipping point, with a resultant delay. The same considerations, of course, apply in the reverse direction for goods and tranships despatched from the city station to outlying small town stations.

The arguments are, however, not all in favour of the use of a city station for tranships. The presence of tranship goods, unloaded on to the stage early in the day and oftentimes not reloaded until late at night tends to block the platforms and increase the cost of operation. Further, the station accommodation may be limited, and, owing to the presence of works and other buildings, extensions would be highly expensive, whilst the existence of tranship sheds would probably enable the interception of foreign stock and the reloading to better advantage into local stations, thereby saving wagon mileage, and, if the flow of traffic be greater in the direction in which the traffic is passing, possibly effecting a reduction in wagon haulage.

Broadly speaking, a tranship station is most

advantageous on a line fed by a large number of branches on which are situated a number of small towns, but such a station would not be of the same utility on a line running north and south, or east and west, with but few branches. On the latter, transhipment can probably be more economically performed at large stations in conjunction with the legitimate traffic of such stations.

THE PROPOSED GOODS CLEARING HOUSE.

In connection with the subject of terminal operation mention may be made of the New Transport Co.'s idea of one centralised goods station for the whole of London. The suggestion comprises the construction of a specially designed "Clearing House," provided with electrical machinery on the various floors to facilitate the loading and discharge of wagons, and the provision of electrically-operated truckers fitted with an ingenious device which permits—with the assistance of rotating magnets—the transfer of loads from one vehicle to another, and thus accelerates the sorting of goods. Motor lorries would form the means of collection and delivery.

We have carefully examined the suggested system of distribution, and had personal experience of the "trucker'" movement, and there appears to be some scope for this branch of the scheme. But would the erection of such a clearing house warrant the demolition of the seventy-four goods stations in London? If all the traffic of the city consisted of "C and D" traffic, the promoters might have a better case, but as coal, brick, and live-stock traffic could not be conveniently dealt with at the proposed building, it would appear impossible

to abandon the existing goods stations, as facilities for this traffic must be provided in proximity to the consumers who cart to and from the stations themselves.

The problem then presents itself: Would the interest on the constructional cost of the clearing house, its appurtenances and the land required, be equal to the economics due to concentration and the use of electric power in lieu of manual labour?

CHAPTER VI.—RATES AND OPERATION.

Class Rates—The True Basis—"Operating" Rates.

Whilst these papers are mainly concerned with the economics of operation in the light of governing principles, it is essential that consideration should be paid and attention briefly drawn to the facts governing the relationship between rates and operation. For it is abundantly clear that the two are intimately related, and that the ratio rates bear to the value of any commodity will determine, *ceteris paribus*, the quantity of the commodity transported.

It is not our purpose to discuss the purely theoretical aspect of the rates question, already fully dealt with by abler pens than ours; nor do we propose to consider whether rates should be based on the ethical principle of *Leistungsfähigkeit,* i.e., on what the purchaser can afford, and ought to pay, as advanced by Professor Cohn*, or on abstract economic principles, in which the laws of supply and demand and the factor of joint cost are paramount considerations. Rather we must analyse the means by which the commodity of transport may be sold at prices which permit of the greater development of trade and industry, and, correlatively, increased

* "Die englische Eisenbahnpolitik de letzten zehn Jahre Leipzig." G. Cohn. Pp. 65-84.

national prosperity, whilst enabling, by means of the augmented demand, its cheaper and more efficient production and distribution. In other words, we must consider the price charged in its relation to facility and execution of service or economic operation.

CLASS RATES.

Economic forces, influenced by certain factors—of which more will be said—combine to produce a level of rates relatively just to both railways and traders, and doubtless had governmental authority not taken unto itself such a stringent control over railway charges, these would have more readily responded to the play of economic forces. But legislation has, to some extent, prevented this, and it may, therefore, be advisable, before debating matters more pertinent to our title, to briefly discuss the class rates—as authorised by the Railway Rates and Charges Order Confirmation Acts of 1891-2, qualified as these are by the Railway and Canal Traffic Acts of 1894 and 1913.

After the extended inquiry held by the Board of Trade—following the passing of the Railway and Canal Traffic Act of 1888—all merchandise was divided into eight classes: A, B, C, 1, 2, 3, 4, and 5 (the last-mentioned being the highest). The chief considerations in deciding the class to which each commodity properly belonged were:—

(a) Value of the article.
(b) Liability to damage during transit.
(c) Weight in proportion to bulk.
(d) The nature of packing and cost of handling entailed.

This classification of commodities is, of course,

common to all the companies, and is abundantly justified by the considerations quoted. Quite naturally, the value of a commodity should be taken into account, as, in the majority of cases, the higher the value of a commodity, the greater is its ability to pay, whilst the circumstances under which it is tendered for conveyance and the risk incurred by the carrier vary considerably, and such variation is calculated by the differentiation in the classes.

The respective maxima varied, to some extent, between the different companies, and, generally speaking, the scales were graded at a certain rate per ton per mile for the first 20 miles, a slightly lower rate for the next 30 miles, a further reduction for the next 50 miles, and a still lower rate for the remainder of the distance. Now in theory, such differentiation in the authorised maxima would seem justifiable, and superficially it would appear possible to consistently apply such class rates. Yet competent writers estimate the traffic now passing at "Special" or other than class rates at 70 per cent. Since such is the case, it will be well to consider the class rates in greater detail.

The differentiation in the maxima on different lines would appear justifiable on the ground that capital cost may have been heavier on one line, whilst operation may, on account of heavy grades and peculiar conditions, have been more expensive on another. Yet such differentiation would be futile if each of the two companies had a line between any two towns, particularly if the line owned by the company with the lower maxima were the shorter. For the application of the higher maxima by the competing company would mean that the whole of the traffic would pass by the alternative route.

The distance gradation, too, is economically sound, as it is a well-known fact that transportation cost does not increase proportionately with the distance, whilst terminal charges are practically constant. But such gradation, even on the lowest maxima, would require revision if traffic were to be attracted. Certain commodities, cheap in price yet bulky in nature, quickly reach a point where any increase in the rate would prevent the possibility of transport, and it is necessary, therefore, to "cut" such maxima if the traffic is to be carried.

The foregoing comments briefly explain the reason why the application of class rates has generally been found impracticable, and one is thus led to consider the varied reasons for the adoption of special or exceptional rates, and to endeavour to trace their economic justification.

THE TRUE BASIS.

The manufacturer of most important commodities is able to ascertain the exact cost of each article he manufactures and to add thereto a reasonable percentage for profit whilst covering general expenses. If it be possible to secure an order by a small reduction in price, he can fix the minimum at which he will still gain a margin of profit. Some there are who imagine that such reckoning may be applied to the cost of and price levied for the service of transport. This undoubtedly is responsible for much of the discontent amongst the public and criticism of railways by those who are ignorant of the true facts of the case.

The cost of the service of transport for any given commodity cannot, under the varying conditions of

railway operation, be even approximately calculated. The first insuperable difficulty is the division of the expenditure for any given work. Though railway economists have endeavoured, by means various and ingenious, to allocate the different items of railway expenditure they have been unable to determine such a relatively simple matter as the division between passenger and goods traffic, and though estimates have been formulated, many of the charges have been allocated to one head or another by arbitrary decision, and not as a result of positive knowledge.

The fact of the matter is that the major portion of railway expenditure is incurred on behalf of the traffic as a whole, and but few items can be dissected and definitely located. The relationship between fixed and fluctuating expenses will be discussed in the consideration of "Operating" rates, but it might here be said that the fixed charges average from 55 per cent. to 65 per cent. of the total expenditure Now these fixed charges remain the same whether goods or passenger traffic preponderates during a given period. They are joint costs incurred for the traffic as a whole. Interest on capital must be paid, the road maintained, the expenses of administration met whether there be much traffic or little, though this statement must be somewhat modified under exceptional circumstances.

Even the operating expenses evade dissection in many phases. It may be possible to compute the cost of engine power, train staff wages, and any work performed on behalf of a particular traffic, but it certainly would not be possible to accurately determine what proportion of the signalling, maintenance and administrative expense is occasioned by the passage of a given train. To elaborate the imprac-

ticability of utilising this principle we might assume that the expenses could be divided between the passenger and goods traffic. Would this ensure the consistent application of the principle? Goods traffic varies to an enormous extent, and it would indeed require a neat mathematical calculation to determine the relative proportion of the signalling, maintenance and other expenditure which must be borne by each category of traffic.

Even were it possible definitely to locate the relative expenditure to each particular category of traffic, such allocation would be vague and transient, as the general conditions and particular circumstances under which traffic is conveyed vary from hour to hour. Whilst the density of traffic coupled with the accommodation for train operation has an immediate bearing on cost of service, climatic conditions undoubtedly influence it still further, and such considerations alone will serve to demonstrate the fallacy and impracticability of the cost of service basis.

In the case of low grade traffic, it should further be noticed, the estimated cost of service will often exceed its value to the purchaser; wherefore the rates charged on such a basis would impede the flow of the traffic and render necessary the enforcement of a still higher payment on the existing and more remunerative traffic, owing to the reduction in the units for transportation.

It may be regarded in the light of an axiom that the greater the quantity of traffic carried, the smaller is the cost of conveyance, and, therefore, the rates charged must in no case be so high as to impede the natural flow of traffic, provided always that the rates are never so low as not to cover the extra cost of the conveyance of the traffic to which they respectively

refer*. These, then, speaking generally, are the basic principles in cost of service and the charging therefor, and we may now consider their economic justification and the method of their practical application.

What are reasonable rates? Are they such as will bring in the maximum profit per unit to the railways, irrespective of any other consideration or those which will permit the due development of trade? Will the application of low rates attract sufficient traffic to warrant their introduction? How must any particular rate be based?

Now, we have seen that the bulk of the expenditure of a railway is caused by the traffic as a whole, and no fluctuation in either class will affect such charges. Such being the case, this expenditure can be altogether ignored in fixing any particular rate, though it must receive due consideration in fixing rates generally. For it is manifest that it is beneficial to the railway to take any traffic which will merely cover its operating cost. In any event, the fixed charges will have to be paid, and it is clear, therefore, that any rate is better than no rate providing such does not result in loss. For fixed charges are then spread over a larger volume of traffic with a correspondingly lower cost per unit.

Thus originates the principle of "charging what

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* For elaboration, see Acworth's terse injunctions :—

I.—Get traffic. The more traffic carried the less it costs to carry. Therefore, first and foremost, get traffic.

II.—Charge no rate so high as to stop the traffic from going : subject to

III.—That no rate shall be so low as not to cover the additional cost incurred by the railway in dealing with the traffic to which the rate applies.

P. 71, *et seq.* "Elements of Railway Economics." W. M. Acworth, M.A.

the traffic will bear," a policy not of extortion, as some economists have termed it, but of moderation. Such a principle is adopted in ordinary commercial and social life. The price of particular commodities varies between the West End of London and the East End. The cost of manufacture may be the same, but the value to the purchaser will differ considerably, for the reason that the goods would not be sold at all in the East End if West End prices were charged, with the probable result that West End prices would rise. Similarly, a doctor will charge a wealthy patient a guinea for a service similar to which he charges a poor patient half-a-crown. The principle is identical. The doctor's establishment expenses will be the same whether these patients attend or not, and whilst in all probability the wealthy patient would seek his advice were the fee doubled, the poorer patient would not, and so the latter must be charged only such fees as he can reasonably afford to pay.

It is now generally understood that fixed charges do not directly affect rates; nor do dividends affect them, except in so far as a road which is paying high dividends may reduce rates lower than it otherwise would, in order to avoid the possible attraction of new capital into the field. But while fixed charges may not be taken into account in constructing rates, the prospective traffic and rates are (or ought to be) taken into account before incurring fixed charges.*

From an economic and a railway point of view, rates must be so apportioned amongst the various commodities as to enable maximum circulation and exchange between producer and consumer, and it is to the interests not only of the railways but also of the

* "Railroad Transportation." Hadley.

general public that rates generally should be so low as to attract a large volume of low-paying traffic rather than a limited volume of high-paying consignments. Thus, as Ripley well says, it is indisputable that the great dynamic force in railway operation inheres in the value of service idea. The cost of service principle might most conceivably be applied to a railway in a purely static state. But, dynamically considered, as involving the growth and development of business, it fails utterly to meet the necessities of the case.*

"OPERATING" RATES.

With the passing of the Railway Rates and Charges Order Confirmation Acts in 1891-2 maximum rates were enforced on the railway companies, but these, though put into operation for a time, were never intended to supplant the existing "actual" rates. "Fixed maxima are of next to no use in preventing extortion," says Professor Hadley in "Railroad Transportation," and this statement was abundantly justified by the welter of confusion into which the enforcement of maximum charges flung the whole question. Subsequent Acts, passed as a result of the outcries of the traders, prevented the railway companies from charging the rates which Parliament, after mature deliberation, had enacted as reasonable, and, speaking generally, rates fell to their old basis. In any event, however, such a condition would have resulted from the ordinary play of economic forces, and the necessity for adjustment between supply and demand.

It will be well to point out here that while railway

* "Railroads: Rates and Regulation." W. Z. Ripley, Ph.D.

companies could reduce their charges they were forbidden—by the Railway and Canal Traffic Act of 1888—to apply rates which would constitute an undue preference, and the enactment also stipulated that there should not be "any difference in the tolls, rates, or charges for, or any difference in the treatment of, home and foreign merchandise, *in respect of the same or similar services.*" By the same Act, competition was recognised—subject to certain conditions—as justifying differential charges, and the system of "grouping," under which the same rates are charged to or from all the places within a given area, was expressly legalised.

Whilst the foregoing affords a clue to many of the apparent anomalies in railway rates, further facts must be adduced before one can logically analyse particular problems. The first important fact to be considered is that railways must—in the interests of their shareholders—convey as much traffic as they can, and that, where sufficient traffic is not forthcoming at the normal rates to exhaust the capacity of the road, it is good business to secure additional traffic at lower rates provided this cannot otherwise be obtained. Of the two items that determine gross earnings, i.e., volume and class of traffic, the former is the more important; granted a large volume of business, even if it be of low class, the railway's earnings will be sufficiently large to make it profitable.

There is a general impression that railways convey at less than cost price certain traffic which cannot bear high rates, and this fallacy we propose to dissipate by discussing the integral constituent elements which have an influence on the rate. Railway expenditure may be appropriated under two general heads :

(1) Charges which are fixed, or vary slightly whatever the volume of traffic; and (2) Operating expenses, which vary in approximately the same ratio as the traffic. Ignoring certain qualifications, which might tend to confuse, the following figures extracted from the half-yearly report of one of the trunk lines will show the relationship of fixed to fluctuating expenses :—

FIXED CHARGES.

Interest on Capital Stock of Permanent Works at 3 per cent.	£1,440,000
Maintenance of Way	232,739
Rolling Stock Repairs ...	167,924
Parliamentary Expenses, Rates and Taxes, Government Duty, General Charges, etc.	177,575
Half Traffic Expenses ...	262,348
	£2,280,586

FLUCTUATING EXPENSES.

Interest on Working Stock Capital at 3 per cent. ...	120,000
Locomotive Power	524,899
Half Traffic Expenses ...	262,348
	£907,247

From a perusal of these figures it will be apparent that for a railway company to be a successful business concern, its earnings, in the aggregate, must be sufficient to cover both fixed and fluctuating expenses, and from this it necessarily follows that it is perfectly reasonable for the rate on traffic which must pass over the line—and which may, therefore, be called the normal traffic—to be high enough to pay its due pro-

portion of these two charges, whilst it is equally reasonable for traffic which could not otherwise be secured to be attracted by low rates which, in themselves, pay their relative proportion of the fluctuating charges and contribute something towards the fixed charges. This statement is, of course, in complete accord with the theory advanced at an earlier stage, viz., "that the relatively high burden of capital cost is reduced in direct ratio to the increase in traffic density, as each additional unit of traffic at normal rates contributes its quota to the fixed charges, whilst traffic conveyed below normal rates contributes in some measure to the general charges immediately its own transportation cost is covered."

It is to the interest of a railway company to get as much traffic as possible, for in the transportation industry, affected as it generally is by the law of increasing returns, operating cost does not increase proportionately with the density of traffic. There are many different phases of operation in which it is necessary to give exceptional rates, i.e., other than normal rates. And in each of these cost of service should be a primary consideration in fixing the rate. But this must not be taken to indicate the average cost of service or any arbitrary amount. Where traffic which cannot otherwise be attracted is carried at a low rate it is but the additional net cost of carriage that should receive consideration*.

Applying this hypothesis to actual conditions, we might assume that between Grimsby and Birmingham very little traffic is passing on account of the high rates between these points, the rates being calculated on the same basis as those from Lincoln to Birming-

* See "Transports et Tarifs" (Colson) for elaboration.

ham. There is, however, a large traffic passing to and from Birmingham via London and Bristol which might be carried via Grimsby if the rate were low enough. Suppose then that the rates between Grimsby and Birmingham are reduced to a figure low enough to attract the traffic yet high enough to pay a little more than the additional cost of conveyance. It is profitable to the railway company to carry the traffic because their fixed charges are little, if any, higher as a consequence, and all that needs to be considered is whether the fluctuating expenses are covered.

In other cases, water competition has an influence on the rates charged, though it must be emphasised that these rates are never below cost. A typical instance is afforded by the meat traffic between Birkenhead and London. This traffic could pass direct to London by water at approximately the same cost per unit as it pays to Liverpool. By sending the traffic via Liverpool, however, an advantage is gained inasmuch as the meat arrives on the London market more expeditiously, but this advantage is measured by a certain definite amount. If, therefore, this amount, constituting the maximum rate which the traffic will pay, is suddenly raised, the traffic will pass to London by water. Thus water competition justifies a decreased rate in such cases, though there are generally other conditions—to which reference will later be made—which enable the railway company to carry such traffic at less than normal rates.

Again, traffic between Hull and London has the alternative of passing by sea or rail. Under ordinary circumstances the traffic will be conveyed by sea, but the railways, by reducing their charges sufficiently,

may secure a portion of the traffic, the quicker transits and better terminal conditions counteracting any excess in the railway rate. Here, however, as in the previous case, the celerity of transport is measured by a definite amount, and if the latter be increased, the former is negatived. In each of these cases, it is the additional net cost that governs the rate. To obtain the traffic the railway companies must offer the lowest rate, but this must not, in their own interest, be less than the cost incurred by the transport, whilst the maximum rate which is charged is dependent on the value of the superior facilities provided, and its relation to the rate by alternative routes.

Not only does the competition offered by other means of transport have an influence on rates, but the competition between different companies tends to cause many rates to be lower than they otherwise would be, though this must not be construed to mean that there is any loss on the conveyance. The statement may be illustrated by the following example:

Between two towns, A and D, there are two competing routes, the first 30 miles in length, and the second, via Y, 40 miles. Were the rates based on the ordinary class rates, the line AYD would have to charge a relatively higher price than the line AD. The value of the service of transport—by which is meant the difference in the value of a commodity at the point of departure and point of destination, or, in other words, its augmentation of place value—would, *ceteris paribus*, be the same in both cases, so that the railway AYD would be thrown out of competition, to the consequent disadvantage of D. To elaborate this, it might be that the line AD runs through country favourable to economical operation,

and that its cost is less than half that necessarily incurred by AYD for a similar distance. In such a case, the longer line would have to reduce its charges to the level of the shorter line or lose the traffic. For the shortest railway route—using the degree of comparison in its broadest sense—between two towns must govern the rate. But what of the town Y, situated at an intermediate point on the longer route? Should it enjoy the benefits of the reduction? There is no competitive force influencing the rate, and it may be that, ton for ton, the traffic between Y and A costs more to transport, from conditions peculiar to its conveyance, than between D and A. Why, then, should the rate between Y and A be reduced? The mere fact that lower rates are accorded to the longer routed traffic does not prejudice the business of intermediate towns, for, in this instance, the traffic would still get to A if the special rate D to A via Y were abandoned. It is then to the interest of Y that this through traffic should pass, as for each augmentation of the traffic, fixed and, to a great extent, operating expenses are spread out more thinly, with the inevitable theoretical result that the particular traffic concerned is not called upon to pay as high a share as formerly of the fixed and other charges.

Again, the obligation of "keeping everyone in business," as the Americans term the equalisation of geographical location, is thrust upon the railways if they are to fulfil their real functions in the social economic sense. The aggregation of industrial units, and the concentration of population into a comparatively few districts of high density necessitates, if the demand for commodities is to be satisfied, the constant widening of the areas of supply. It thus de-

volves upon the carriers to assist the more distant producers by equalising, as far as possible, the prices at the consuming market. Now, so long as the traffic cannot afford to pay, or cannot be obtained at the normal rates, it is to the interest of the railways to quote lower rates which, whilst securing the traffic, will pay immediate cost of conveyance and leave a surplus—small though it be. The following example will illustrate the principle :—

Let us assume that A and B are two agricultural districts, 25 and 40 miles respectively from a large town C, and that the rate from A to C is 5s. per ton. On the mileage basis the rate from B to C might be 8s., but the application of such a rate would effectively prevent produce from B reaching the market at C; would probably depress production at B, and would certainly deprive the railway company of a source of revenue. The railway company, then, after due consideration of B's offer to load a certain quantity per truck, quote a special rate of 6s. 6d. per ton. Surely there is no reason why the A agriculturists should have a grievance. The rate B to C is certainly less per ton per mile than from A to C, but the growers at B still have an additional charge of 1s. 6d. per ton to pay, and, correlatively, to clear, on reaching the market at C, which, it might also be remarked, would have the advantage of the competing products. That such equalisation is fair to all is apparent on analysis. Firstly, the consumers benefit from the presence of additional competition in the home market; secondly, production at the more distant places is stimulated; and, thirdly, the railway company secures additional traffic. The competing producers (at A), though certainly not receiving any direct advantage by such a reduction in B's rate, are

not ill-treated, as the new competitors, though paying a smaller sum per mile for transport, have a larger amount to expend for conveyance. Further, those who have the advantage of favourable geographical location in the case of one market may be very disadvantageously situated as regards another, and a reduction in this case—which would, other things being equal, be readily given—represents a *quid pro quo*.

Even were it possible to ignore the influence which the relationship of fixed to operating expenses has on rates, the manner in which certain traffic is tendered for conveyance would fully justify substantial reductions in the rates on such traffic. Whilst the domestic business of the country is essentially of a retail nature, much of the foreign produce is delivered to the railway company at the port of discharge in train loads, or in sufficient quantities to fill several trucks, and as these are invariably consigned to the huge centres of population it is usually possible to obtain return loads for the wagons. Contrast this with the domestic business. It must be clear that it is cheaper for a railway company to run a train of fully loaded trucks from point A to point B than to start with a comparatively light load and stop at numerous stations *en route* to attach and detach wagons.

The question of the difference of cost of service and its effect on the rates charged was fully considered in the Southampton case of 1895, when the Mansion House Association charged the L. and S. W. Railway with preferring foreign traders and thereby subjecting home merchandise to undue prejudice. The railway company justified the rates by the difference in the conditions under which foreign and home consignments were carried, these respective conditions not

representing the same or similar services within the meaning of the Act. The Railway Commissioners to whom the case was submitted decided that the charges, in the main, were unfounded, and a perusal of the evidence shows that, apart from any other features, the railway company was called upon to perform more extensive services and provide considerably more accommodation for dealing with home produce than imported; for instance, the average load of the import traffic was 4 to 6 tons per truck, whereas the load of home produce was less than 1½ tons. The decision in the Southampton case was to clearly uphold the principle that the concession to consignments carried in large quantities and under conditions favourable to economical and profitable operation of rates lower than those charged on small and irregular lots, the handling and transport of which involved considerable trouble and higher working expenses, does not necessarily constitute an undue preference, and Mr. Justice Collins, in summing up, said: "The mere fact that the goods are foreign goods does not turn a difference into a preference."

Thus we have analysed, briefly it is true, the more important deviations from the normal rates. That on the whole operation has benefited by the application of such differential rates cannot be doubted, and that still further economy can be effected and development be enhanced by judicious experimental rates would appear probable.

Chapter VII.—CONSTRUCTION AND MAINTENANCE OF THE ROAD.

The Road—The Gauge—Initial Constructional Considerations—Grades and Curves—Loops and Refuge Sidings—Maintenance Considerations—Signalling.

In previous articles we have made brief reference to the detrimental effect that faulty construction and inefficient maintenance have on operation, and it is this subject we now propose to treat. It is not the intention to discuss the economics of construction in the technical sense, but merely to consider how the efficiency of operation is enhanced by suitable construction and impaired by constructional defects.

There is nothing in the economics of railway working that varies more than the cost of construction. A railway may be made either cheaply or expensively, according as the purchase of the land involves a large cost or a small cost, as the permanent way is light or heavy, as there is a larger or smaller proportion of double and treble mileage, but it does not necessarily follow that a line which has cost an exceptionally high sum relative to its mileage is a line in which economy has been wanting. The mere arithmetical process of dividing the mileage into the total cost of making the line does, indeed, afford an

index to the capital expended, and therefore to the amount that must be realised in order that certain dividends may be paid upon the cost of construction, but it affords no just criterion whereby to calculate whether the line should have cost more or less, whether the capital expended has been wastefully spent, or whether the results are likely to justify the expenditure.

THE ROAD.

In the Introductory to his book on Railway Economics, Mr. Acworth gives an apt definition of a railway. " Historically and etymologically a railway is," he says, " merely a road on which rails are laid. Originally the rails, whether of stone or wood or iron, were laid flat on the surface, and vehicles with ordinary wheels were free either to use the special track or to move at large over the whole width of the road. In the next stage of development, the rails were continuous iron plates with flanges on their outer edges to confine the wheels to the track proper. In the next stage, the rails were raised above the surface, and the flange was transferred from the rails to the wheels. The railway thus became specialised; it could only be used by special vehicles, and the special vehicles could no longer be used on ordinary roads. Naturally, the railway forsook the public highway and was laid on land allocated to its sole use.

" From the physical point of view, we may then define a railway as a road devoted to the exclusive use of vehicles adapted to run on raised rails. But in practice our definition, even on the purely physical side, goes far beyond this. The object of the

specialised roadway was to secure economy in the cost of haulage, and at a very early period it became evident that economical haulage was inconsistent with the curves and corners and the climbing up and down hill of an ordinary road. And so we have the bridges, viaducts and embankments, the cuttings and tunnels, and all the costly 'works' which belong to our modern idea of a railway."*

Regarding British railways solely, we see, then, that the primary essential is the establishment of a road—the construction of the bed and formation and the laying down of rails with their necessary appurtenances: chairs, fastenings and sleepers—designed in as true alignment as the configuration of the country and the money at the disposal of the promoters will allow; for, as D. H. Ainsworth points out, "the location of a railroad is giving it its constitution. It may be sick, almost unto death, with accidents of construction and management, but with a good constitution it will ultimately recover."

Various questions have, of course, to be considered in connection with alignment, for whilst the diversion of the line to a town lying to one side of the proposed route may necessitate greatly disproportionate constructional expenditure, it may be to the interest of the railway to make such diversion, though, in this regard, the amount of capital available is a most important consideration.

THE GAUGE.

Whatever may be the relative merits of the different gauges—and there will always be varied opinions—one point is clear. There should be no

* "The Elements of Railway Economics," W. M. Acworth, M.A. Pp. 5-6.

break of gauge in a country, or indeed on a continent. Diverse gauges react adversely on operation, for they necessitate transhipment of goods and passengers and reduce the area of fluidity of rolling stock. It is unfortunate for Australia that the different provinces did not adopt some uniform gauge —whatever it might be—at the commencement, as now that the necessity for cross-continental routes and through connections is apparent, this question of gauge is of supreme importance. A recent conference recommends complete unification, and this involves the conversion of 12,718 miles of narrow gauge railway to the standard gauge of 4 ft. 8½ in., at a cost of £37,164,000, an enormous sum, a large proportion of which represents clear economic waste—du directly to the lack of foresight of an earlier generation.

Regarding the suitability or otherwise of the British standard gauge, there has always been controversy, and whilst many regret the disappearance of the G. W. broad (7 ft.) gauge, it must be admitted that whilst such a gauge would have assisted the evolution of the locomotive, and possibly have facilitated train operation *per se,* that incubus in British commerce—the retail business—could not have developed to anything like its present extent unless the railways were satisfied to haul a still greater proportion of dead to paying weight.

In connection with the gauge there is a fallacy which should be exploded. Some there are who believe that the present standard gauge is directly responsible for the restricted dimensions of rolling stock, but this is wrong. Such dimensions are limited by the size of tunnels and bridges, and the point should be observed that if, on the inception of

railways, the comparatively few tunnels had been given larger dimensions, many of the present-day locomotive difficulties would have been avoided.

Further than this, loads of large dimensions would have been conveyed with much greater facility, for already are the restrictions of the loading gauge most seriously felt in the conveyance of such consignments as large ships' boilers, during the passage of which all traffic on immediately adjoining roads has temporarily to be suspended; indeed, should the capacity of these consignments considerably develop, the railways' ability to carry may be greatly impeded, and thus render enforced migration of certain manufactories to the sea-board.

American railways, profiting by British experience, allow greater headway with an unhampered loading gauge, and it is interesting to consider how very seriously the development of the huge resources of that vast Continent would have been impeded if the railways had to suffer the severe restrictions prevalent on English roads.

INITIAL CONSTRUCTIONAL CONSIDERATIONS.

Another necessity which adds largely to constructional cost is the purchase of land when widenings are required. On the opening of any railway the traffic offered is limited, in some cases because a competing line has the monopoly of the business, which is diverted but slowly, and in other cases owing to the undeveloped nature of the country traversed. The general tendency, however, is for the traffic to increase—always providing there is sufficient present and potential traffic to support the lines in the aggregate, without which the line would probably never

have been built—and eventually a point may be reached when widening becomes essential. At this point the economy and advantage of reasonable foresight will particularly be experienced. If, when the railway was built, sufficient land were purchased to meet the present necessity, and overbridges prepared in anticipation of possible widening, the cost of the additional facilities will be limited to the expense of laying a new road or roads; but if, on the other hand, these precautions were not taken, the increased cost will be far more than proportionately greater. Land will be exceedingly costly—particularly if it is built upon—for the mere fact of its being adjacent to a railway will render it more valuable, and the owners, knowing full well the extreme necessity for purchase, will "bleed" the railway company to the utmost farthing. Further, Parliamentary authority is necessary for compulsory purchase, and this means considerable expense which would be avoided were the land already secured. Again, whilst the walls of underbridges can be lengthened and independent girders erected, the alteration of overbridges costs practically as much as a complete renewal.

It would, therefore, appear economical and advantageous for a sufficiency of land to be purchased at the time of initial construction wherever there is the remotest possibility of widening being necessary, also for all overbridges to be erected with a span sufficient to permit of the widening of lines. Had this only been done in earlier days, much of the heavy capital expenditure now found to be necessary would have been avoided.

The absence of sufficient capital may, of course, provide an effective bar to this economic provision,

but it should at least be possible to obtain an option on the land which may possibly be required.

GRADES AND CURVES.

Reference has previously been made to the adverse effect of grades and curves on traffic working, and further attention will be paid to the subject in our paper on Locomotive Operation, when indication will be given of their considerable effect on the hauling capacity of the locomotive and the life of wheels.

Whilst the ideal perfectly level and straight road is an impossibility under English conditions, it is necessary that lines should be constructed as near to this ideal as conditions will allow. To facilitate operation it is desirable, *ceteris paribus,* to have a long grade of, say, 2 miles of 1 in 200, rather than 1 mile of level and 1 mile of 1 in 100, as on the latter there would be considerably greater resistance and increased tractive effort.

The necessity of reducing curves to a minimum is well indicated by the fact that a 16 chains curve offers approximately the same resistance to the movement of a train as a grade of 1 in 100. Quite apart from this detrimental influence, the construction, renewal, and maintenance of a curve are more expensive than a straight road: firstly, because check rails are required on all curves sharper than about 12 chains; secondly, the outer rails of curves wear very quickly, notwithstanding the superelevation provided; and, thirdly, it is more difficult to keep curves in true alignment than is the case with straight road, and the effect of their being out of line is more perceptible.

The necessity for suitable curves is well described in a recent report to the International Railway Congress: In bringing about safe and smooth running, the great importance of transition curves in the running roads is well appreciated by all engineers responsible for the maintenance of railways, but the presence of transition curves is of much greater importance in the case of curves immediately approaching and leaving junctions, and to avoid what inevitably must happen without such transition curves, viz., a swing or a jerk at the entrance to any curve from the straight and departure from same to the straight. Should derailment due to a curve occur, it almost invariably takes place at the entrance to a curve, owing to the absence of such treatment, rather than to the presence of the curve itself, and it is at these points where discomfort is most usually experienced. Again, with the approach curves so treated, a train more readily accommodates itself and travels much more comfortably over a curve and through a junction, and the necessary absence in most cases of sufficient superelevation is not so appreciably felt. Where suitable transition curves are provided trains can, with safety, be run at higher speed through junctions than would be desirable without them, and the capacity of the line is therefore increased.

LOOPS AND REFUGE SIDINGS.

On lines over which it is proposed to work both passenger and goods trains the necessity for accommodation to enable the faster trains to pass the slower is obvious, but the methods to be adopted therefor are debatable.

On lines of very low traffic density the practice of shunting across the road is probably economical provided trains are timed accordingly, but even in such cases it is desirable to provide refuge sidings in some places, which should be of sufficient size to accommodate the longest train. Recently, the length of refuge sidings, rendered too short by the somewhat sudden increase in the size of train loads during the last ten years, and the physical impossibility of lengthening many of them, has been the cause of considerable difficulty in operation, the advisability of constructing in advance of immediate requirements thus again being emphasised.

To use these sidings it is necesary for trains to run past, then back in, and when the road is clear, re-cover the line previously traversed—an apparently unproductive utilisation of energy and time, which would appear to render the provision of loops, connected by facing and trailing points with the main line, more economical. This will probably be the case if the loop is of such length as to enable its facing points to be operated from one existing signal-box and its trailing points from another, but if this is not possible, and an additional box is rendered necessary to control the exit from the loop, with increased maintenance and operating expenses, the economy becomes doubtful.

There is no doubt that both time and energy are wasted in connection with the use of refuge sidings; therefore, on lines of high traffic density, where adjacent existing boxes can be made to control either end, loops will be found particularly economical and advantageous.

MAINTENANCE CONSIDERATIONS.

The efficient maintenance of the road has an important effect on operation. The formation level of a railroad is, of course, an artificial one, and its present form has only been built up by the construction of cuttings, tunnels, embankments, bridges, and viaducts. All these works affect maintenance in varying degrees. On embankments, for instance, there may be splendid drainage, due to the bed of the road having been made of suitable material, and thus the formation is consolidated, the cost of maintenance being reduced to a minimum. On the other hand, in cuttings it may be almost impossible to effect good drainage with the result that, unless the bed of the road be taken out and replaced by special material, the water lying under the sleepers is forced out by passing trains, this washing away the ballast holding the sleepers in position, with the result that sleepers kick, keys work loose, chairs break, and, generally, maintenance is very costly and careful supervision necessary.

These and many other circumstances have to be considered by the maintenance staff, and theirs is no light task. Unless the absolute safety of the road can be guaranteed, the efficiency of operation must be impaired. To ensure the highest state of efficiency, due inspection must be made of cutting and embankment slopes, walls and roofs of tunnels, abutments, girders, and crown of bridges, and the superelevation of the outer rail on curves, whilst all points and crossings should be regularly and minutely examined.

In regard to the maintenance of a length, no hard and fast rules can be laid down, as the circumstances and conditions vary considerably, e.g., one length

may be undermined by colliery workings and consequently be troubled with subsidences which, though awkward in themselves, admit of good drainage being effected in the necessary lifting, whilst on another length there may be a clay foundation too near the sleepers, and in this case the difficulty is to effect good drainage.

The secret of a good road is the efficiency of drainage, and any fault in this is dangerous. An embankment is sloped at its correct angle of repose, but after hot weather followed by continuous rain, it often happens that the water percolates through the cracks and crevices caused by the heat, and should there be defective drainage there is every likelihood of a slip.

The superelevation of the outer rail on curves is necessary to counteract the rectilinear motion of locomotives. The maintenance staff are provided with tables carefully calculated to certain radii of curves, and care has to be taken that the cant is never less than the given height, except where necessary to meet special cases, as at junctions, points, and crossings. Where it is not possible to allow sufficient superelevation, speed restrictions have necessarily to be imposed.

The elimination of speed restrictions in connection with junctions is important, from the fact that every permanent condition necessitating the reduction of speed is a constant factor detrimentally influencing the earning capacity of the line, and in a measure tending to increase the cost of working and maintenance. Further, having regard to the increasing demands of the public for expeditious travel, and also to the strenuous competition between companies to secure the utmost proportion of long distance

traffic, it is essential that all speed restrictions should be eliminated as far as possible. If the almost paramount consideration is to be the further shortening of the time occupied on the journey by travelling at still higher average speeds, then having due regard to the safety and comfort, not only will it become necessary to consider the question of improvements at junctions, but in addition, that of improving curves in many parts of the main lines, so as to reduce the limitation of speed to a minimum.

On falling gradients, where high rates of speed are run, the outer rail of curves is kept well up; the superelevation is gradually increased until the full height is attained at the commencement of the curve, maintained uniformly over the whole length, and run out from the end of the curve. Reverse curves, or curves with very short pieces of straight road between them, are specially treated, and on these it is generally necessary to impose speed restrictions.

In furtherance of the principle that lines should be so laid as to provide for probable future requirements, the fact that trains running in any two of the four possible directions comprised in an ordinary junction impede the passage of trains over the inner lines, requires consideration. Wherever physical and other conditions permit it is probably economical to provide flying or burrowing junctions, though the somewhat heavy gradients which they necessitate are likely to have an adverse effect upon traffic working over lines where heavy goods and mineral trains distinctly preponderate, an effect which would be but slightly felt in connection with a preponderating passenger train traffic. Their desirability should,

therefore, necessarily be considered in connection with the traffic that will pass over them.

A most important subject in connection with permanent way maintenance is the proper conservation and prompt supply and distribution of material. To meet emergencies, and for ordinary maintenance purposes, each ganger must have a stock of material on hand, and for these the district engineering inspector must be responsible; the latter must also see that the quantity of each is kept down to the lowest point compatible with safety and efficiency. There should be facility of transference of second-hand material from one inspector's district to another, and returns of stock on hand, when received and how disposed of, should be rendered periodically to the stores superintendent, who, as the recognised head of the stores department of the railway, must have supreme control over the supply and distribution of engineering material.

New material should, as far as possible, be dispatched from place of manufacture direct to the point at which it is required, thus obviating intermediate handling and storing, and in this connection particulars of all material required for the various relaying works should be in the hands of the stores superintendent in ample time to enable the stores to be supplied by the date required; otherwise the work of relaying will be retarded until the autumn or winter, carried out with a considerably enhanced wages bill, and the relaying gang probably employed on unimportant work during the most favourable months of the year.

The greatest possible life may be obtained from permanent way material by its gradual gradation from main line to goods line, from goods line to

siding, and every care must be exercised in this respect to delay as long as possible its relegation to the scrap-heap.

Relaying must necessarily be performed with a minimum of inconvenience to train running, so that everything possible is done prior to actual stoppage of the line, this being effected on Sundays or when traffic is extremely light. The size of the permanent way gang has particularly to be studied; it will necessarily vary with the extent of the length and the density of traffic passing over it.

The area of each district inspector's supervision should be such as can easily be covered, so that he may keep in touch with the various gangs. The district inspector himself should at least once a week thoroughly examine the permanent way in tunnels situated in his district; in fact, he should manage to walk the whole of the district within the week; in this way alone can proper supervision of the work of the gangs be exercised. Likewise, the sphere of the district engineer is bounded by the extent which he can economically supervise, frequent visits having to be paid to all parts of the district for purposes of inspection and discipline.

SIGNALLING.

Various departures from the ordinary mechanical system of signalling have been made in recent years, power-operated installations having been fixed on many stretches of line. The great point in favour of a power system is, of course, the facility for the concentration of levers, enabling a reduction in the number of boxes and a proportionate decrease in the wages bill. Secondly, the amount of labour

required in operating points and signals is reduced to a minimum, and the signalman is thereby encouraged to exercise his brains in preference to his muscles. Thirdly, the system lends itself to an elaborate installation of track circuiting, and therefore tends to promote safety in working, as also does the automatic raising of signals to danger immediately on the passage of a train and the "indication" given in the box in connection with the operation of switch movement.

Power installations are, however, essentially costly, and are, therefore, only warranted in circumstances of good traffic density, where the quick and intermittent passage of trains is a prime necessity.

The utility of intermediate automatic block posts, controlled from (it may be) a mechanical box, on long sections has already been alluded to. These fulfil the functions of an intermediate signal-box, and therefore have the effect of halving the time interval necessary for the passage of trains through the section, thus considerably aiding evenness of train operation.

Whilst the maintenance costs of power installations are generally higher than in the case of mechanical systems, considerable saving may be effected if care be exercised in the initial laying down of the plant, particularly in connection with the pipes or cables connecting the levers with the switches and signals.

CHAPTER VIII.—LOCOMOTIVE DESIGN AND PRACTICE.

Features of Locomotive Development—Locomotive Elements—Hauling Power and Economic Value — Locomotive Practice — Superheating — Compounding—The Fuel Problem—Water Softening.

The whole range of railway operation is affected by locomotive problems; on the suitability of the locomotive hinges the efficiency of service. Just as the practical demonstration of the utility of the locomotive in the early part of the nineteenth century settled the question of the " movement agent," so the locomotive now governs the whole question of transportation.

It is not our purpose to discuss the more technical details of locomotive design, nor enter into detailed comparison between steam and electric locomotives, though the effect of a possible application of the latter type will receive subsequent reference. Our main object is to discuss the potentialities of the present-day locomotive and its efficiency for the conduct of general rail transport.

FEATURES OF LOCOMOTIVE DEVELOPMENT.

In the light of our modern knowledge the history of locomotive development is worthy of brief review

from the economic standpoint, for there are several instances in which certain alterations in locomotive design were originally introduced for purposes quite different from those for which science has since proved their particular utility.

The locomotive was slow in coming with the discovery of steam as a motive force. Space was required in which to generate the large volume of steam needed; and it was not until the tubular boiler and artificial draught made by exhaust steam had been invented that the locomotive became an effective tractive agent.

The principle of steam locomotion was first applied—by Symington, in 1785—to a vessel which was employed to draw barges along the Forth and Clyde Canal. About this period several engineers made suggestions for constructing locomotive engines to run by steam, Richard Murdoch and others making models, but Richard Trevithick was the first to effectively tackle the problem, producing first a road locomotive and then a railway engine (1804). This engine included features inseparable from modern practice, as in it were introduced high-pressure steam, horizontal cylinders, and the crank axle The tractive effort was about 4 lb. per lb. of mean steam pressure in the cylinders. Trevithick introduced an innovation which, when its practical utility was appreciated, had a wonderful effect on the efficiency of the locomotive. A nuisance was caused by the emission of the exhaust steam into the air, and to overcome this the exhaust pipe was carried through the water tank into the chimney; thus he was very close indeed to the important discovery of feed-water heating and condensing.

Time passed on, but still the smooth rail presented a supreme difficulty, Blenkinsop overcoming this by placing a rack at the side of one of the rails and attaching teeth to a wheel which engaged the rack. Hedley, however, when his attention was directed to the steam engine, decided that he would dissipate the fallacy that a heavy engine with a smooth wheel in contact with a smooth rail would not give sufficient adhesion to propel a train, and accordingly made elaborate tests with a carriage mounted on four smooth wheels and carrying a weight equivalent to that of an engine. His experiments were successful, and flanged and rack rails disappeared for all time as an essential part of railway construction.

To Stephenson, however, belongs the credit of developing the locomotive into a practicable high-speed machine suitable for operating railway traffic as distinct from slow-speed coal haulage, and to him, also, the introduction of the multitubular boiler is due. It would be of little avail here to discuss the history of locomotive development beyond this point, as in their essential particulars the engines built by Stephenson are similar to those now used, various improvements, of course, having from time to time been effected.

LOCOMOTIVE ELEMENTS.

The modern locomotive consists of three parts: the engine, the boiler, and the tender. Of the two former elements, the size of either has a direct bearing on that of the other, for the length of the boiler is governed almost entirely by the wheel-base, and the diameter by its relation to that of the driving wheels. The success of an engine depends

primarily upon the boiler, since the power developed is limited by the amount of steam which the boiler is capable of supplying, hence this will first be considered.

The three constituent elements of the boiler are, of course, the firebox, the smokebox, and a cylindrical body containing the tubes which run from the firebox to the smokebox. The constantly increasing demands for more powerful engines have led to the development of boiler dimensions to such an extent that the limitations in diameter imposed by the loading gauge have practically been reached. Limitations of grate area demand intense combustion, which has necessarily to be induced by forced draught, and a large heating surface is provided to satisfactorily utilise the heat thus generated. The use of a large number of tubes—from 200 to 300—forms an essential feature of the modern boiler (the adoption of superheating being ignored for the present) and primarily enables the requirements enumerated to be effected.

The three main factors determining the capacity of a locomotive are: (1) The boiler, or steam making apparatus, (2) the cylinder, or steam using apparatus, and (3) the weight on the driving wheels, or what may be termed the adhesive element; the points to be studied in connection with its economic construction and utilisation are: The hauling capacity, the relative proportions of the various elements making for efficiency, the point of effective work, the utilisation of fuel, and how the hauling power may be increased correlatively with a diminution in fuel consumption, and, under some circumstances, maintenance charges.

The primary dimensions of a locomotive relate to* :—

1. *Grate area.*—This determines the amount of coal that can be burned per hour, and consequently the amount of heat units available to be translated into energy of motion.

2. *Heating surface.*—This determines the amount of heat from the coal that can be used to convert water into steam, and consequently, the percentage of heat energy that will be utilised for this purpose.

3. *Boiler pressure.*—This determines the amount of energy that can be stored in a boiler of a given size and weight, and also affects the efficiency of the machine as a whole.

4. *Cylinder dimensions.*—This determines the amount of steam at a given average pressure that will be consumed per stroke, and consequently the number of strokes (and the number of driver revolutions) per minute that can be made without using steam faster than it can be produced.

5. *Driving wheel diameter.*—This determines the speed of the engine as compared with the speed of operation of the cylinders. The area of the piston in the cylinder determines, for a given average steam pressure, the total pressure transmitted to the driver. The ratio of the length of the stroke of the piston to the circumference of the driver determines what percentage of this pressure is communicated to the rail by the driver as propelling force.

6. *Weight on drivers.*—This determines the

* "Economics of Railway Operation." M. L. Byers.

amount of propelling force on the rail that can be utilised before slipping begins.

Likewise the hauling power of a locomotive is dependent upon the suitable relationship of three main factors, viz.: (a) Adhesive power, (b) size of cylinder, and (c) size of boiler and firebox and steam pressure.

The adhesive power is dependent upon the weight on the driving and connected axles, and is usually estimated as one-quarter of that weight in dry weather and one-fifth when the weather is inclement. Present-day English permanent way engineers object to more than from 19 or 20 tons being placed on any one axle, and more wheels, therefore, have necessarily to be connected if the adhesive power of an engine is to be increased beyond that point.

On particularly level roads single-drivers are, generally speaking, quite suitable, and these were used by the Great Northern Company for many years, but where gradients are at all severe and trains heavy, the adhesion must be increased.

On lines with heavy gradients it is often found necessary—for efficie t working—to couple six wheels, i.e., three axles, on passenger engines, although, given dry weather, engines with four-coupled wheels may be worked satisfactorily. Of late years practically all goods engines have been designed with not less than six-coupled wheels, whilst the engines utilised for hauling heavy mineral trains have been built with eight-coupled wheels, a weight approximating 20 tons being placed on each of the four axles. In order to briefly show the additional adhesive power obtained by the connection of a greater number of wheels, let us assume

that 19 tons be placed on each axle; then the adhesive power of

a single driver would be $\frac{1}{4}$ of 19 tons = $4\frac{3}{4}$
a 4-coupled engine „ $\frac{1}{4}$ of 19 × 2 = $9\frac{1}{2}$
a 6- „ „ „ $\frac{1}{4}$ of 19 × 3 = $14\frac{1}{4}$
an 8- „ „ „ $\frac{1}{4}$ of 19 × 4 = 19

Attention must now be turned to the tractive force, *i.e.*, the actuating power of the engine. This is obtained by pressure of steam behind a piston head which is connected to a crank, this transferring the reciprocating motion of the piston to the rotary motion of the wheels and axles. The extent of this power is, therefore, dependent on the diameter of the piston head, length of stroke and the pressure of steam behind it, whilst another factor which is all-important is the diameter of the driving wheels. These factors bear varying relationship to the cylinder tractive effort, the theoretical equation usually employed being :—

$$\text{Cylinder Tractive Effort.} = \frac{\text{Pressure} \times \text{dia. of Cyl.}^2 \times \text{Length of Stroke} \times .85}{\text{Diameter of Driving Wheels.}}$$

.85 being a constant inserted to account for the fact that the full pressure of steam is not always behind the piston head towards the end of each stroke, owing to cut-off, the utility of which will receive due consideration.

It is but seldom that the locomotive, viewed as a steam engine, exercises its maximum working capacity, as a greater tractive force is required to start a train from rest than to haul it when once in motion, hence the necessity for adjustable valve gears, such as are not required on stationary engines with fixed loads.

It would, of course, be absurd to build a locomo-

tive with a certain adhesive power and a corresponding cylinder tractive effort, and fail to provide a sufficient supply of steam to fully utilise these forces; a definite relationship must, therefore, exist between the size of the boiler and firebox, the size of cylinders and the adhesive power.

Boiler tractive effort—as the force obtained from the boiler is termed—is determined by the heating surface and speed required of the engine. The following equation is usually adopted to determine it, the figure 146 being a constant decided on by engineers after many years' experience :—

$$\text{Boiler Tractive Effort} = 146\,\frac{\text{Heating Surface.}}{\text{Speed in miles per hour.}}$$

It must, however, be explained that the boiler tractive effort is generally in excess of theoretical requirements to allow for bad quality of coal, furring of tubes, priming and faulty firing. The increased size of boiler, of course, adds to the adhesive power which must always have an advantage over its theoretical computation on account of disturbing factors, such as greasy rails, etc.

HAULING POWER AND ECONOMIC VALUE.

Consideration may now be given to the economic value of a locomotive, determined, as has been indicated, by the hauling power and subsidiary forces.

Train resistance on the level is estimated at 4½ to 5 lb. per ton of dead weight once the train is in motion. Gradients naturally vary this figure; on an up grade of 1 in 100 resistance is increased to about 20 lb. per ton when the train is running at

from 10 to 15 miles per hour. On curves there is added resistance owing to the friction between the flanges of the wheels and the outer rail, the resistance on a 16 chains curve being estimated as equal to that on a 1 in 100 up grade.

To ascertain the economic load, therefore, both tractive force and train resistance must be considered. Against the tractive force obtained by means of the equations given previously must be calculated the load according to the ratio between the weight of the train and its resistance, affected as this is by gradients and curves. Moreover, consideration must be given to such variable items as friction in motion of engine and the retarding effect of head and side winds.

Now, as we have said, everything depends on the suitability of the locomotive for its particular work. It would not be economic to put an engine with eight or ten-coupled wheels to haul an express passenger train, nor, on the other hand, would it be wise to place a heavy coal train behind an engine specially designed for fast work. Economy demands that the service and the type shall be compatible. What, then, are the characteristics of the different classes? A passenger engine designed for high speed running must have reserve boiler capacity, for, as the speed increases, so will the demand for steam. With heavy goods and mineral train engines, however, the capacity to haul is the prime consideration, and therefore maximum adhesive and cylinder tractive forces are necessary.

LOCOMOTIVE PRACTICE.

Having thus generally treated the particular factors governing locomotive design, it will be advisable to trace modern development before proceeding to discuss the economic devices introduced of late years.

When it was found that the increasing weight of passenger train loads was proving too much for the 4-4-0 engines, the "Atlantic," with its 4-4-2 arrangement, enabling a longer boiler and larger firebox to be carried and greater power to be generated, appeared, and for a considerable time held its own. During the last few years, however, there has been diversity of opinion as to the value of this type. The limitations of the "Atlantic" are that sufficient haulage power cannot be attained, and it has a further disadvantage in that the coupled wheels forming so small a proportion of the total wheelbase create oscillation, and that outside cylinders as generally employed are the cause of an alternate pull from the centre of gravity, which adversely affects the alignment of the road. Again, owing to the immediate contact of outside cylinders with the atmosphere, condensation is particularly prevalent. On some lines, without extraordinary gradients, where a fast regular service with moderate loads has to be maintained, the "Atlantic" still holds sway, as the type offers special facilities for ample heating and grate area, but where adhesion is the primary consideration, the "Atlantic" is, in most cases, being replaced by the 4-6-0 type.

On lines with an important and heavy passenger traffic, the latter type is now in general favour, for with the same number of wheels as the "Atlantic,"

the six-coupled arrangement not only gives greater adhesive weight, but enables the axle load to be distributed more evenly, to the resulting benefit of track maintenance costs. Further, this type of locomotive fulfils all modern requirements in the matter of speed, and possesses a reserve of power necessary in these days of constantly increasing train loads.

The 4-6-2, or "Pacific" type, is a logical outcome of the six-coupled locomotive, but is only represented by one engine on one railway in Great Britain.

In connection with goods and mineral train engines, it is interesting to note that since the introduction of the 0-6-0 type, the demand for higher speed and increased size of boilers has resulted in the employment of leading wheels, or bogies, while increased tractive effort has in some cases been obtained by coupling another pair of wheels. The necessity of hauling heavily loaded trains has been met by a decrease in the diameter of the coupled wheels and enhancement of the boiler power, though such elements do not, of course, enable very high speeds to be attained. For heavy goods and mineral traffic the eight wheels coupled type has long been in general use, whilst the introduction of the "Consolidation" (2-8-0) type is growing in favour.

Of recent years efforts have been directed to improved methods of steam raising with a view to effecting economy, but whilst it may generally be said that superheating, compounding, and feedwater heating have all proved of some utility, the former is the only method which has found much favour in England.

SUPERHEATING.

With the growth in weight of train loads, and the necessary limitations of the locomotive using saturated steam, the necessity for higher boiler pressures became apparent. Superheating had for many years been in the minds of engineers as a remedy, but difficulties of valve and cylinder lubrication at high temperatures prevented its adoption until recently, when these were overcome by the discovery of suitable oils and suitable design of the working parts. In its favour are many advantages, as, for instance, the reduction of losses due to condensation, more efficient expansion, and reduction in boiler maintenance costs in the fact that a superheated engine of similar haulage power to a saturated steam engine works with a lower boiler pressure.

Undoubtedly the most important feature adopted in locomotive construction, and the one most likely to result in considerable economies in fuel, it would certainly appear to be the saving factor in the steam engine for purposes of locomotion in its competition with electricity. Consisting, as it does, in the raising of the temperature of the steam after formation in the boiler, superheating affords results similar to those obtained by increasing the working pressure of the boiler.

It would be invidious for us to enter into a discussion of the various types of superheater, which are all based on the same principles. Suffice it to say that the saving in fuel and water consumption, and, incidentally, labour in firing, is considerable. In comparing superheated and saturated steam, Professor Goss, the American expert, proves that the power developed at 160 lb. pressure is from 10 to

16 per cent. greater in the case of the superheated locomotive, and as a result of recent trials on "Atlantic" passenger engines in England, it has been found that the saving in coal consumption is from 12.11 to 15.8 per cent., and on eight wheels coupled goods engines as much as 25 per cent.

From the point of view of English railway working superheating is particularly desirable, as the increased production of steam is equivalent to an increase in the size of the boiler, the latter in actual practice being almost an impossibility owing to limitations of gauge; also, existing boiler pressures for given loads may be reduced with the consequent economy in boiler repairs, etc. Again, the loss of effective power owing to condensation in the cylinders is practically nullified, as the temperature of steam above saturation point is available for counteracting the cooling influence of expansion. Moreover, there is practically an entire absence of priming, as any water that may be carried along with the steam from the boiler is completely evaporated in passing through the superheater elements. In the same way a more gaseous nature is imparted to the steam, thus improving its expansiveness.

A still further point is that the capability of engines, otherwise obsolete for main line work, can be maintained and their life considerably extended by the installation of the superheater. With this, and the substitution of larger cylinders, many years of valuable work may be obtained from machines which, under ordinary circumstances, would have been engaged on quite subsidiary services, and have earlier been relegated to the scrap-heap.

COMPOUNDING.

Quite distinct from the conversion of saturated steam into dry steam, in order to effect greater efficiency, is the principle of compounding. This aims at obtaining from the steam its maximum expansive power by utilising high-pressure and low-pressure cylinders. Whereas in stationary and marine engines the principle of compounding is general in conjunction with condensation of exhaust steam—which latter has never been applied to locomotives owing to the absence of accommodation for the purpose—the application of compounding on locomotives has not met with much success in this country, although a few companies possess compound engines.

For express passenger train work compounding has been found to result in a better utilisation of the steam than is possible in simple expansion engines. The principle consists in the exhaustion of the steam from one or more high-pressure cylinders (to which it has previously been admitted direct from the boiler) to one or more low-pressure cylinders of larger diameter. The most useful type of engine in this connection is perhaps the "three cylinder," the steam exhausting from one high-pressure to two low-pressure cylinders.

The cylinder proportions must be so arranged that the combined effort is as continuous as possible, otherwise the engine would not be balanced in a very important particular, and heavy shop repairs would be the result. The greatest tractive force of the locomotive is generally required at starting, consequently a special valve is provided to enable live steam from the boiler to be admitted direct into the low-pressure cylinders, and thus it is also possible

to work the engine as simple expansion. The possibility of such interchangeability in working is particularly appreciable when starting off with a heavy load or climbing a heavy grade, a reversal to normal compound working being made when sufficient momentum has been obtained, or the summit of the gradient has been reached. Owing, also, to the greater evenness of crank movement, there is a steadier blast, with the consequent reduction in loss of fuel. As a set-off to these advantages, however, there is an increase in the cost of construction and running repairs.

Mr. Edgar Allen, in his concise work, "The Modern Locomotive," states that "a considerable fuel economy, amounting in some cases to as much as 20 per cent., is definitely admitted to have been found in the working of compound engines. . . . Meagre as they are, the results published in this country incontestably show the compound to be a more efficient and economical machine than the simple engine."

Experiences on the Continent would seem to indicate that the adoption of superheating on compound engines would provide the maximum efficiency of the steam, if certain difficulties in the compound principle could be successfully surmounted.

THE FUEL PROBLEM.

Suffern and Son, in their "Railroad Operating Costs," provide food for serious reflection when they allude to the manifest tendency for the cost of fuel to increase. This is not only a matter of immense moment to the railways, but it is an important economic factor

which justifies close study for the purpose of determining whether there are methods by which the present vast consumption may be diminished, and the subject will be further alluded to in our paper on locomotive operation.

Dr. Goss, in 1906, conducted a series of tests for the purpose of determining the best methods for the utilisation of fuel for locomotive purposes. These tests were conducted with a simple expansion locomotive equipped with a superheater, and the result of the tests was found to demonstrate that, under ideal conditions, of all the available heat in the fuel consumed by the locomotive, 57 per cent. is absorbed by the boiler and superheater, and the other 43 per cent. is distributed in heat losses, as follows* :—

Products of combustion..................	19 per cent.
Imperfect combustion	17 ,,
External radiation and leaking	7 ,,

Now, fuel economy may be effected by various means. The reduction in losses due to imperfect combustion would immediately cause an improvement, and it would appear that the suitable size of the "blast," the correct form of the brick arch and the exact slope of the deflector plate are all matters relevant to this subject. For the function of the blast pipe is a most important one, and its suitable proportion is a necessity for efficiency. It should be designed so as to admit the steam from the cylinders to exhaust in the most effective manner, and thus, by the withdrawal of air from the smokebox cause sufficient vacuum to assist combustion.

The brick arch and the deflector plate—both of which are fitted inside the firebox, the former under

* Sufferns' "Railroad Operating Costs."

the tubes and the latter over the firehole—are very necessary for suitable combustion, as by their use the heated gases on leaving the fire are compelled to pass backwards—towards the firehole—to clear the arch, and are thus brought in contact with the cold air through the firehole, which, directed on to the fire by the deflector plate, causes any combustible particles to combine with the oxygen, thus adding to the firebox capacity, because the more complete combustion forces each pound of coal burned to yield a higher percentage of its total heat units.

The greater utilisation of heat in escaping gases may be effected by the heating of feed-water before its injection into the boiler. If this principle were successfully adopted there is no doubt that considerable fuel economy would result by the fact that the water would have a certain temperature before entering the boiler, and would consequently require less heat to raise it to the ebullitionary stage.

Many factors have an influence on the fuel consumption, and it would seem puerile to instance some of the comparisons now made for the extension of economy, for the tonnage and speed of trains, the traffic conditions and physical characteristics, all have an appreciable influence on the question. Increased evaporation per pound of coal may be obtained by the due extension of superheating—referred to previously—whilst the more systematic education of firemen would probably lead to substantial economies in steam consumption, and thus a diminution in the fuel consumed.

The recent colliery strikes brought the question of oil fuel into prominence, particularly in view of the fact that one or two British railway companies,

whose locomotives were so fitted, utilised this kind of fuel to considerable advantage, and on other lines engines were hurriedly adapted. Its vast possibilities, including its facility of transference from point to point, may, in some countries, induce enterprising companies to lay down pipe lines for the conveyance of the fuel, and thus rid themselves of the enormous expense involved in the purchase and distribution of locomotive coal, although the lack of natural supplies will probably prevent any general use of oil for locomotive purposes in Great Britain.

WATER SOFTENING.

An additional factor in the economic problem, which in past decades has not received the attention its importance merits, is the necessity for the suitability of the water used in locomotive boilers. If the water is hard in nature it forms incrustation on the tubes and interior of the boilers, and should it contain any amount of suspended sewage, etc., in solution, this frequently creates a froth on the top of the water and causes priming, i.e., ingress of froth, water, etc., into the cylinders along with steam through the regulator. Such has, of course, a detrimental effect on the cylinders, as water will not compress, and priming quickly lowers the level of water in the boiler. In addition, it adversely affects operation, in the fact that it is necessary, when an engine is priming—in addition to opening the cylinder drain cocks—to pull in the regulator, and thus allow the engine less steam, which means slower running.

In order to overcome this difficulty, expensive water softening plants have been installed at some

places; an extension of such installations would probably prove advantageous, for there is no doubt that as the firebox plates and tubes are thereby freed from the harmful effects of scale formation, which causes burning of plates and tubes, there is a saving of fuel due to their increased conductivity, whilst the greater durability of these elements, with consequently reduced boiler repair bills and a greater factor of safety, are other advantages of the use of pure water that should not be overlooked.

Chapter IX.—LOCOMOTIVE OPERATION.

Power and Resistance—Double Heading and Banking—Locomotive Operation—Fuel and Water Consumption—Location, Lay-out and Routine of Locomotive Depots.

The consideration of economic locomotive operation is largely bound up with the question of train loading, dealt with in a previous paper. Its more immediate importance lies in careful driving and efficient running depot administration. Every large railway system may be said to possess its own peculiar conditions for traffic manipulation, and it may be taken for granted in the first place that engines are built and arrangements are made to meet those conditions.

POWER AND RESISTANCE.

In any investigation of the conditions affecting the working of trains the power exerted by the locomotive occupies in the majority of cases the first place, for it is a well-known fact that the *vis viva* increases with the speed attained and diminishes with the weight of the train. If the weight and load of the trains remain the same, the questions relating directly to this *vis viva* would depend on the variations of speed. The conditions affecting the running of high speed trains would then require a special investigation which would not be applicable

to trains running at average speeds, and still less to those running at low speeds.

The increase in the weight of locomotives is an immediate consequence of the continual increase in the demands made on the power of the locomotive. Not only is it necessary to haul as large train loads as possible, but there is also a demand for increasing the speed of passenger trains, which are at the same time becoming heavier; this necessitating an increased adhesive weight and larger boiler and firebox.

The work done in hauling a train from one point to another in a given time is made up of the factors: weight, speed, and distance. If the speed is increased, then to enable the same engine to do the work the weight must be reduced. The resistance to be overcome by the locomotive should also receive due consideration. It is either fixed, as in the case of gradients, curves, etc., or variable, as in the case of bad weather, high winds, or greasy rails.

In considering railway speeds it is too generally assumed that the effect of a gradient of a given length and steepness is always the same wherever the gradient may occur. This is far from being the case. A rise of, say, 10 miles of 1 in 200 immediately from a large junction station, at which all trains stop, is much more detrimental than if the gradient succeeds a downhill stretch, the impetus from which assists the train up the opposing slope.

In curves resistance to speed is naturally encountered. Here, however, the indirect effect is more to be feared than the actual augmentation of the resistance. In England all curves except the sharpest are passed with only a slight diminution of speed caused by the friction of the flanges on the rails,

Now and again, however, one meets with curves of so small a radius that, in the interests of safety, speed is purposely decreased while passing over them. This, of course, entails a much greater loss of time than in the previous case, where it is scarcely perceptible, for as reported by a prominent British railway engineer to the International Railway Congress, " with a sound track, on a well-drained foundation, maintained in good line and level, and with the entrances to and exits from curved sections properly prepared by spiral transitions, trains may safely attain speeds in miles per hour on the curved sections (within reasonable limits of curvature) equal to eleven times the square root of the radius in chains."

DOUBLE HEADING AND BANKING.

Another aspect of the question of heavy loads and grades should here be considered. The " double heading " of passenger and goods trains and the " banking " of goods and mineral trains is a recognised phase of operation, and it would be well to consider the relative advantages and disadvantages of the methods.

As a matter of principle it is unreasonable to use two engines to haul one passenger train. The drivers cannot act quite harmoniously, the power of the engines is not so well utilised; forces acting in opposite directions and causing the couplings to break are more to be feared; long and heavy trains are more difficult to manage; the operation of the continuous brake is more difficult, and stops and slacks take longer; watering the engines also leads to loss of time. The same is true of station service, which takes longer with lengthy trains, especially

when there is the complication rendered in many instances by the shortness of platforms. On the other hand, considering train movement *per se,* it is equally certain that it is preferable to run a single train where such a course is known to avoid difficulties with train connections and the shunting of slower trains.

It is difficult to say exactly when it is advantageous to resort to banking. It is essentially a question of circumstances. It may depend upon the length of the difficult section of road, its position in relation to the nearest stopping stations, the configuration of the line, the load and speed of trains, the power and type of engines, etc. Perhaps it may, therefore, generally be said that "banking" is advisable over short and severe gradients, as the use of the additional engine enables a heavier load to be hauled by the train engine for the remainder of the journey than would otherwise be the case.

LOCOMOTIVE OPERATION.

The efficient manning of engines is a matter of primary importance. The system under which drivers are promoted step by step from unimportant to the more important "jobs" is a logical and commendable one. The commencing grade of cleaner affords the aspirant opportunity for gaining a knowledge of the various engine parts, but the severity of the line of demarcation between the "running" and the "shed" staffs is to be regretted, for it rarely happens that a cleaner is able to gain practical experience in the fitting of the parts: valuable experience would no doubt be gained by future drivers

were they for a time billeted as fitter's labourers instead of having their duties restricted to cleaning work.

It is important that the fireman should have a knowledge of the main principles of combustion and of what occurs in the firebox, so that he may coal and manipulate the dampers to the best advantage. No definite rule can be laid down for firing an engine; regularity of firing, or "little and often," together with a thin fire, is the most essential point. The economy of thinness of fire, however, depends primarily upon the size of grate and the class of coal, Welsh coal, for instance, requiring entirely different manipulation from South Yorkshire. It is by no means easy to maintain a full head of steam and yet prevent the engine "blowing off" furiously when standing. Suitable acquaintance with physical conditions (grades, etc.), and uniform firing should, however, assist to obviate this. The fire should be maintained at a uniform thickness, and excessive firing, which reduces the efficiency of combustion, avoided.

The keenness of the blast renders thin fires on small grates inadvisable, and in such cases a slight thickening of the fire to prevent induction of superfluous air is necessary. On the other hand, large grates demand thin fires with an even distribution of coal, thus allowing contact with the air and complete combustion. Care in firing will largely prevent formation of clinker and bare spaces on the bars, both considerable disadvantages, the former causing a supply of air insufficient for complete combustion, and the latter allowing cold air to impinge on the firebox, generally reducing efficient grate area, and causing a rush of air which carries with it

the small particles of burning cinders, subsequently emitted from the chimney in the form of sparks and often causing considerable damage to property on the line-side.

The fire, of course, has to be regulated according to the character of the road, care being taken that no fuel is put on just prior to the regulator being closed. The more constant the pressure in the boiler the better, as, apart from uneconomic operation, contraction and expansion due to sudden changes injure the plates. When an engine is standing, or running without steam, the damper should be closed and the injector put on in order that the steam may be prevented from "blowing off." From observation it is particularly noticeable that substantial waste occurs through this duty being neglected, and firemen should for this, if no other reason, maintain a fairly thin fire, so that immediately the blast caused by the exhaust steam ceases the heat produced decreases.

Inspection of each engine before departing from the shed is essential, and equally important is the driver's attention to the trimmings in the big ends, eccentrics and other bearings, and general lubrication. Lack of care in this respect will often result in hot bearings with their concomitant delays and extra cost of repairs.

For reasons both of economy and safety it is essential that the driver should have a thorough knowledge of the road and grades over which his engine runs, and be aware of the location of all signals and speed restrictions, either permanent or temporary. In regard to goods and coal trains the driver should be particularly acquainted with the gradients, as, owing to the strictly limited brake power, the train must always be well under control, otherwise

he may be unable, on a down grade, to pull up at a signal—particularly in wet weather, when the rails are in a greasy condition—and thus render possible a mishap. In this connection the utility of "sand-drags" is manifest; these have proved most efficacious in bringing a train to a stand even when the driver has wholly lost control over it A gradual opening of the regulator is also essential, as sudden starts have a tendency to snap the couplings, owing to the excessive strain to which they are subjected.

The prime duty of the engine crew lies not only in the efficient working of the engine, but also in running it as economicallv as possible. To drive a locomotive with the highest effective point of economy, the capacity of the engine must be suitable to the weight of the load it is required to haul, taking into consideration the physical conditions of the road and the quality of fuel and water. Further, the expansive properties of steam must be utilised to the best possible advantage, and this can only be accomplished by dexterous manipulation of the expansion links. The sooner the steam is "cut off" prior to the full stroke of the piston, the greater is the expansion of the steam from which the piston derives its momentum, so that immediately an engine gets into its stride the reversing gear should be notched up, thus reducing the length of time the ports are open on each stroke. In this connection the utility of a free reversing gear should be apparent, for it is manifest that drivers will more readily and suitably handle equipment which requires the least possible expenditure of energy. On some of the larger engines, especially in America, steam is used as an aid to the movement of the reversing gear, and it may be that power-actuated reversing gears

will form a standard feature of locomotive design in the near future.

FUEL AND WATER CONSUMPTION.

The consumption of coal is a matter of primary importance in connection with locomotive operation, and in this connection drivers have it in their power to effect considerable economy in two ways, viz., (1) by carefully utilising the steam, obviating "blowing off," and closing the regulator as early as practically possible when descending banks and preparing for stops; (2) by closely controlling the methods of the firemen and seeing that they apply coal at the proper time and in reasonable quantities.

In this matter, moreover, once again is encountered the question of loading, as the heavier the load the greater, of course, is the coal consumption. Loading carried beyond the point of maximum economy will result in slow travelling, necessitating lengthy sectional margins, and consequently frequent shunting (across the road if there be but few loops), and time standing; thus will ensue frequent stopping and starting again from a state of rest, the latter condition necessitating considerable extra consumption to generate the maximum possible steam pressure in order to get the train in motion, in addition to probable " blowing off " when unexpectedly shunted, and extra mileage created in " setting back " into sidings.

The water used for locomotive purposes is supplied from three main sources. i.e., (1) by pumping, (2) by gravitation, and (3) from water companies' mains. The price necessarily varies in different localities, that under the third head being particularly

high. There appears to be no definite rule whereby enginemen can acquaint themselves with the columns from which the cheapest supplies may be obtained, and thus make efforts to regulate their demands accordingly, and it would appear that economy might be effected by the employment of distinctive colours for water columns, so to afford clear designation of those governing the most favourable terms.

The capacity of the tender tanks is another important point in the water question; these on the larger engines are capable of conveying 4,000 gallons, which, of course, constitutes a heavy dead load. The adoption of water troughs has, therefore, been of great utility as, with the assistance of a scoop arrangement, water may be picked up at speeds of more than about 30 miles per hour, and thus the necessity of stopping to replenish is avoided. The extension of this arrangement would appear economically justifiable—though the capital cost of installation is somewhat heavy—in view of the ever-growing necessity for long non-stop runs and increased traffic density.

LOCATION, LAY-OUT AND ROUTINE OF LOCOMOTIVE DEPOTS.

On the location and lay-out of the depots hangs to a great extent economic locomotive operation. For the efficient and prompt supply of locomotive power it is essential that every railway system should have a complement of district locomotive depots, at each of which a certain number of engines may be stabled and kept in repair, the quantity in each case varying according to the amount of work to be performed and the number of booked "jobs." The depots must

essentially be located at those places where the necessity for power for working trains arises, such as, for goods and coal traffic, sorting sidings and marshalling yards; and for passenger traffic, at important termini and in thickly populated districts having a large local service. In many instances one district depot may serve to fulfil the requirements of both classes of traffic, and it is always imperative, for the avoidance of light running—a directly unremunerative expenditure—that the distance of the depot from the point of origin of the traffic which its engines have to convey, should be as short as possible. Besides the depots already named, various subsidiary (and smaller) ones are also necessary for the provision of general relief both in engines and men.

The functions of the depot should be not only the supply of engines, but their maintenance in good repair and the performance of what are known as "running repairs," the scope of which will vary according to the size of the shed staff and the plant and equipment provided. A depot stabling a large contingent of main line and express passenger engines will, for instance, require a well organised plant and a capable staff of fitters and boiler-makers, whilst a smaller depot, with but few passenger engines and a small number of goods jobs will only require a small staff and equipment.

The locomotive depot should, then, be as near as possible to the main line. There should be two lines of way connecting the main line with the shed roads; this will tend to prevent any possible delay in the event of derailment, collision, or other contingency on a single outlet. If the depot be an important one it is desirable that the branch should be connected

with a goods road or shunting loop to prevent the possibility of light engines interfering with main line traffic.

An essential detail in the lay-out is that separate roads should lead to the turntable and the coal stage, otherwise the work of coaling engines will be hampered. Likewise, it is advisable for the sheer-legs and weighing machine (where one is provided) to be on separate metals; otherwise the weighing machine will be rendered inaccessible when there is an engine receiving repairs under the sheer-legs. A water column should be situated between each pair of shed roads, and ash pits provided on the shed roads, just outside the shed and near the water columns, so that the process of obtaining water and cleaning fires and smoke-boxes may be proceeded with at one and the same time.

In the main there are two kinds of locomotive shed, viz., (1) the round, and (2) the oblong type. Perhaps the main disadvantage in the "round" type is the necessity for turntables, with the concomitant liability to delays in the event of engines coming off the road and fouling the tables. Nowadays the tables are worked by electricity, and this facility has tended rather to enhance a type of shed that was beginning to lose favour.

The "oblong" type of shed, closed at one end, necessitates a certain amount of shunting of dead engines, but the difficulty is to a great extent overcome by the two-ended shed, which enables engines to run in or go out at either end. The building of such sheds, however, is limited to localities where there is an abundance of land alongside the main line, enabling a through connection in each direction with the necessary sidings, etc.

For the encouragement of efficient working and due care of engines, it is desirable that as far as circumstances will allow, each driver, especially of passenger trains, should work the same engine week in and week out, and the " links " in the daily roster should be so arranged.

Constant record must be kept of the working of engines over the line by means of returns rendered from the depots to the running superintendent; only in this manner can a true idea be had of the working of the department. In like manner, weekly reports of the state of every engine on the line must be rendered; thus may be gauged the precise condition of the engine stock over the entire system.

Whilst ordinary running repairs may be effected at the depots, important and far-reaching repairs and alterations have necessarily to be carried out at the central shops, and in this connection the point at which the line of demarcation should be drawn is an ever debatable one. In some instances the intervals between which engines leave and return to the shops are of remarkable duration, and considerable temporising has then to be effected in the running sheds. The more this course is adopted, the more nearly approached is the American idea of getting the quickest maximum use out of the machine, and it is a moot point whether it is true economy to lengthen the period out of shops and rely on extraneous running repairs or to have a systematic arrangement for the return of each engine for thorough overhaul when a stipulated maximum mileage has been run, varying maxima being detailed according to the class of work performed.

As regards the depot routine, it is of primary importance that every engineman should be fully cogni-

sant of the "job" for which he is booked, and that he should receive timely notice of all alterations affecting his working.

Before a locomotive goes into traffic it should be thoroughly cleaned; this is an important part of the maintenance, as not only is it necessary on grounds of economy to carefully clean the motion, etc., and thus remove foreign substances which may cause friction and consequent wear, but as a matter of policy locomotives should be turned out with their general exteriors cleaned and polished, as excellence in this direction commands the respect of the public and enhances a company's reputation.

A further essential is the regular washing out of locomotive boilers. The poorer the quality of the water encountered in the different localities, the shorter must be the period between each washing out. The prompt removal of the scale which quickly forms in the boiler is necessary both for increased efficiency and increased life of the boiler. In this connection, the installation of hot water washing out plants is of considerable advantage. Such a plant enables engines, after "blowing off," to be washed out with water at about 150 deg. F., and refilled with water at about 200 deg.; thus the engine can be ready for traffic again in two and a half hours, a direct saving—when compared with cold water washing out—of ten hours in its utility thereby accruing.

All engines must be subject to constant, thorough and systematic examination, a work which should be performed both daily and periodically. Before an engine is allowed to leave the shed it should be examined by a fitter and a boiler-maker, a record of whose examination should in every instance be

made. A thorough and more complete examination of the various parts must be made at periods varying from one to three months, according to the relative importance of the parts, particulars being recorded in log books and incorporated in a return to the running superintendent, those responsible for the examination in each case appending their signatures to the document. Thus will the immediate location of responsibility be effected, and such a system inaugurated as will ensure maximum precautions for safe running and proper and efficient care of the locomotive.

In the primary arrangement of the engine running, the headquarters staff under the running superintendent should be the deciding and directing instrument, the working diagrams for each depot there being drawn up, and due consideration paid to location of depot, nature of road to be covered, length of non-stop run and load—particularly the latter for freight engines—hours of duty, facilities for providing relief, and arrangements for return trip.

Chapter X.—ROLLING STOCK.

Passenger Vehicles—Goods and Mineral Wagons—The Problem of Wagon Distribution.

The two primary factors to be considered in connection with passenger, goods and mineral rolling stock are (1) economical design, and (2) maximum utility. Both of these are very important, but whilst the first applies equally to all classes of vehicles, the second must be qualified to some extent; it certainly applies with equal force in connection with goods and mineral wagons, but with regard to passenger vehicles it should, under certain circumstances, be defined as "reasonable utility," for the crowding of a train to its utmost capacity may have a tendency to drive passengers to competitive means of transport, and thus cause a decrease in the passenger receipts.

PASSENGER VEHICLES.

Taking passenger vehicles first, one finds varying sets of conditions corresponding to the different services for which the vehicles are required.

Owing to the demands for greater speed and increased comfort in travel, during the last thirty or forty years, the size and weight of passenger stock has increased to a remarkable extent. Forty years ago, the dead-weight per passenger was only 4 cwt., whereas with an ordinary third-class vehicle of the present day it is over 6 cwt. per passenger, whilst with corridor coaches it is as much as 10 cwt. per passenger, increases of 50 and 150 per cent. respec-

tively. Thus the cost of operating per passenger has risen tremendously.

Railway officials appear, however, to be taking the matter to heart, insomuch that it is becoming the custom in newly constructed coaches to provide the utmost possible seating accommodation, amounting to eight for each third and six for each first class compartment in corridor coaches, and twelve and eight respectively in ordinary vehicles. The necessity for inter-communication between sections renders it essential that corridors should remain on the long distance trains, and ordinary comfort demands the due provision of lavatories and other conveniences. It would seem, therefore, that the dead-weight hauled as a direct result of the provision of these facilities cannot be decreased.

In connection with dining cars there is, however, an opportunity of effecting economy in haulage, as the running of these vehicles accounts for a considerable proportion of the heavy operating expenses of express trains. In England the first-class passenger wants his accommodation for meals entirely distinct from the third class; thus separate first and third class cars have to be run, and on most lines the passenger can travel in them for the whole of his journey. In Germany they have an economic way out of this difficulty, for one coach alone serves to provide food and refreshment for the various classes of passengers. Travellers may enter this "Speisewagon," as it is termed, at any stage of the journey, order what refreshment or meal they require at a fixed tariff, and return to their own compartments as soon as they have partaken of it; thus the one vehicle serves the needs of a whole train-load of passengers.

A move has been made in this direction by the pro-

vision of a kitchen car, which supersedes the first and third class dining cars, on some lines, e.g., London and South-Western and Great Central. The cars have a tare of, approximately, 40 tons, and are constructed with the kitchen in the centre, one-half of the coach being reserved for first-class and the other half for third-class diners. These cars, which, under normal conditions, are reserved exclusively for the purposes of the catering department, would appear to mark the first step towards the adoption of the "Speisewagon" system, and as by their use the (what may be termed) non-productive weight hauled is diminished by 100 per cent., their introduction would appear justifiable. The "Speisewagon" idea, if generally introduced, would undoubtedly lead to substantial economy both in operating and in catering, but to secure its favourable reception the opposing forces of English class prejudice would first have to be overcome.

There is considerable difficulty in determining the economical accommodation necessary for provision on any given express train. It will, of course, vary considerably, according to the season of the year and slightly according to the day of the week, and it is essential that close watch be kept upon the number of passengers conveyed day by day; it is only in this way that a fair idea can be obtained of the true point of maximum economy. There is no reason why the journals of guards in charge of corridor trains should not contain a column for the insertion of the number of passengers travelling between "stopping" stations. Such particulars would cost nothing to obtain, and would, when considered over a period, afford practical and conclusive evidence of the maximum accommodation requisite for the train.

The great drawback to the economical operation of express trains, with few exceptions, is the presence of separate classes. Recently active steps have been taken in this direction, so that none of the through services now possess more than two classes. But two classes still remain, and until they have been merged into one, maximum economy of operation will not be reached. The disadvantage of the duplication of classes lies in the unnecessary haulage which is bound to ensue and in the extra shunting and marshalling which is entailed. The requirements of the public have, however, to be considered.

This brings us then to the general consideration of interchangeability. The more interchangeable a vehicle, the more useful it is. This does not mean to say, however, that in practice whole coaches of first-class compartments are the most economical on all lines. The amount of first-class traffic varies on different railways according to the districts they serve. Generally speaking, the first-class difficulty can be met half-way by the provision of composite coaches, for few trains, express or suburban, require the running of entirely first-class coaches, unless such coaches be occupied in part by brake-van accommodation. Composite coaches, moreover, are useful as reserve stock to meet extraordinary demands. They are imperative for "slipping" purposes, and in this connection save the unnecessary slipping of two separate coaches. The conclusion to be drawn, therefore, is that composite coaches are more interchangeable, and, correlatively, more economical, than first-class coaches, provided always that the railway's first-class traffic be an average one.

This question of interchangeability should receive due consideration in deciding on the particular design

of new stock. Vehicles which may be of great utility for long-distance excursion trains in the summer may be of little or no use for short-distance work in the winter. The most effective distribution of corridor stock should, therefore, be made, as the provision of an undue proportion of this class of vehicle is by no means economical, its use for unsuitable work merely increasing the dead-weight hauled and needlessly restricting the seating capacity. Inversely, it would be unwise to stint the supply of corridor stock, for the reason that the absence of what is now regarded as a necessary comfort of travel might unfavourably impress passengers and react adversely on the revenue of the railway company.

The demands of the suburban service are not by any means so far reaching as those of the express service. Luxury takes a good second place; passengers in a train for only a brief period do not require the space that long-distance ones do; moreover, the suburban traffic is generally low-rated, i.e., composed of season tickets, etc., and, therefore, does not warrant the provision of high-rated accommodation.

Considerable economy is derived by running passenger vehicles in train-sets, operative in the express and the suburban services respectively. In the express services, the sets perform fixed workings, and as their time comes for lifting and repairs, each can be withdrawn *en bloc* and its place filled by a train composed of reserve or spare stock, thus obviating taking one coach out at a time and generally upsetting the formation. Every effort is necessary to get the lifting, etc., of regular express trains completed, and, in fact, to get the maximum amount of stock out of the repair shops prior to the

commencement of busy seasons, so as to have an adequate reserve to call upon to meet additional demands. As regards the suburban services, the utility of the train-set is all the more in evidence owing to its interchangeability and to the practically constant requirements of the particular traffic which it has to convey.

In order that the utmost possible use may be obtained from passenger stock other than that running in fixed workings, its distribution must be effected by a central control, which must be kept advised of the requirements at the different centres and of the amount of stock on hand to meet those requirements. This necessity is particularly evidenced in connection with the runnng of excursions and the requirements of theatrical and other special traffic.

GOODS AND MINERAL WAGONS.

In endeavouring to arrive at the most economical size and design of goods vehicles, one has first to examine the characteristics and requirements of trade, as there must be a correspondence between the unit of purchase and the unit of load. The retail character of the business of this country necessitates frequent and limited supplies, with short hauls and quick deliveries, conditions differing essentially from those operative on a large continent, such as America, where large supplies and big stocks are the rule, where distances are greater, and means of communication more limited.

Between the many factors having an influence on the economical utilisation of passenger and goods vehicles there is an important difference arising from the fact that, roughly speaking, freight is transported

in order to be destroyed in production or consumption. In consequence, as a general rule, each individual ton of freight moves in one direction only, while each passenger moves in two, the bulk of the freight traffic being almost invariably in one direction, while the movement of passengers is reciprocal and balances itself out and return. This difference has its effect on the rolling stock. Its effect is also seen in the fact that the passenger fares are usually as great in one direction as in the other, while in regard to freight traffic the rates are usually lower in the direction of least movement.

The first consideration in the construction of goods wagons for general purposes is to provide a vehicle for which it will be possible to secure at all times of the year, and in both directions, a load reasonably approaching its maximum capacity. The volume of traffic offering, therefore, determines the question of economy in connection with the class of wagon to be used for its conveyance. Many commodities carried in large quantities are of such bulk that the actual weight which can be placed in a wagon is considerably less than the maximum load of the wagon, and thus in such cases it is of importance to obtain the largest available floor space.

We are therefore brought to the consideration of economical capacity. Commenting on this phase of the subject, a reporter to the International Railway Congress* stated that the capacity of a goods vehicle may be considered from three points of view :

(1) *Tonnage*, i.e., the maximum weight a vehicle can carry;

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* *Vide* "Study of the most economical capacity of goods wagons, etc." Question XVIII., Paris Congress.

(2) Dimensions of the body, or rather *cubic space* available inside it;

(3) Area floor space, or what comes to the same thing, the *length* of the vehicle, because the other dimension, the width, can only vary within very narrow limits;

and that one or other of these three factors needs consideration, and occasionally more than one of them, in determining the type of wagon that must be used in a given case.

In the matter of large wagons, perhaps too much attention is paid to weight instead of cubical capacity. For the purpose of conveying an adequate traffic of light and moderately heavy manufactured goods between any two centres, the greater the cubical capacity provided on a safe and efficiently working wheel-base of two pairs of wheels, the more economical the transport, "adequate traffic" here being made to apply to such as will utilise at all times the whole cubical capacity of the truck between centre and centre. Maximum cubical capacity can only be attained by means of the covered van. The 15-ton covered van has therefore been found advantageous between large centres; its wheel-base, moreover, can be so constructed as to fit existing turntables.

The road being laid for the conduct of transportation at the lowest possible cost, it follows that it should conform with the requirements of the stock passing over it. In any general increase in the size of stock the immediate abolition of turntables would be impossible owing to lack of accommodation at many of the large goods depots. There is no reason, however, why the possible future requirements of the stock should not be borne in mind in connection with new works.

Turning to the question of open goods wagons, the same remarks apply respecting tare-weight, shunting and accommodation. However, these wagons necessarily convey, and are intended to convey, the heavier articles of manufacture, affording, as they do, ready receptacles for craned goods. Owing, again, to general and organised systems of transhipping and the very stringent loading rules which are now being enforced, the average load per wagon has in the last few years gradually increased so that there is a definite call for wagons of more than the usual 9 and 10 tons capacity. Under these circumstances, the 12-ton open wagon is becoming the most economical.

For the conveyance of their own coal for locomotive purposes, many of the railway companies have indeed enlarged as far as possible the size of their wagons—bogie all-steel wagons of 30 and 40 tons capacity not being unusual—but these have to be restricted to certain pits where they can pass under the screens.

Respecting large wagons of the American type, Colonel Yorke, in his report on the railways of the United States, points out: "A great deal has recently been said about the long freight cars used in America, and English railway managers have been criticised for not adopting cars of equal dimensions in this country. I think some misapprehension occasionally arises on the subject. *The important factor in the case is not the length of the car, but the carrying capacity of the car in relation to its weight.** American freight cars are all carried on bogies, and as a rule there are eight wheels to a car. Their carrying capacity varies from

* Italics by the authors.

30 to 50 tons, and their tare weight from 15 to 20 tons. One of the most popular forms of car appears to be the 50-ft. steel-framed car, with a capacity of 50 tons (2,000 lb.) and a tare of about 20 tons, the total weight per axle being 17 tons 10 cwt. So long as these proportions are adhered to, it makes no difference, so far as the cost of transportation is concerned, whether the load is carried in one car with eight wheels or in two cars with four wheels each. That is to say, the result will be the same if, instead of one car of the size and weight mentioned, two cars are employed, each with a capacity of 25 tons and a tare of 10 tons, and each having four wheels. Not all the cars in America offer such favourable terms as those just mentioned. The box cars have, as a rule, a carrying capacity of 30 to 40 tons, and a tare of 16 to 18 tons, the paying load in each case having a less proportion to the dead load than is the case with the 50-ton cars."

"There are serious difficulties in the way of introducing, for general service in England, wagons of great length. The sidings, goods sheds, weigh-bridges, turntables, coal tips, screens, etc., are, as a rule, quite unsuitable for wagons of the dimensions named, to say nothing of the usual conditions of trade, which are based on the present style of vehicle. It is sometimes suggested that English companies should forthwith reconstruct the whole of these works and appliances, but no one has as yet estimated what the cost of such alterations would amount to. It is probably incalculable, and the question arises, whether after all this vast expenditure had been incurred, and the whole trade of the country had been disorganised during the transition period, the saving in handling the traffic would pay the interest on the

outlay. The four-wheeled wagon will, therefore, in all probability remain the standard wagon of the country, *and economy is to be sought in improving the design of such wagons, and increasing their capacity in relation to their tare, rather than in introducing wagons of greater length.*"*†

Just as conditions vary in different countries, however, so they vary in different districts. Certain centres of production and consumption call for particular types of wagon, and organised systems of transhipping, resulting in the concentration of aggregate loads for particular districts, have a tendency to increase the requirements.

Wagons of large capacity have, *inter se,* many advantages over medium or small wagons, such as carrying a greater load as compared with the tare, occupying less yard space, and requiring a smaller amount of shunting, but owing to the difficulty in continually finding full loads for them in both directions, they may not be economically used to any great extent. A point in favour of the medium or small wagon is, then, that there is a better prospect of profitable back-loading, as any advantage gained by the use of the large capacity wagon on the forward journey would very often be more than counterbalanced by its being returned with a very light load

The whole question of the economical working of goods and mineral traffic must largely depend on the relative proportion of "dead" to "paying" weight hauled, and as the larger the capacity of the wagon, the smaller relatively is the tare, and the larger, therefore, the carrying capacity per ton of dead weight, it is manifest that large wagons are more economical

* Italics by the authors.

† "Railways" (E. R. McDermott). Pp. 98-9.

when the volume of traffic warrants their use. Such conditions operate when traffic is offered in large and regular quantities and for a lead of considerable length; and when the commodity carried is one which will not bear any but the lowest rates, the practice of utilising high capacity wagons becomes not merely sound, but absolutely necessary.*

The existence of natural streams of traffic has a powerful influence on the proper selection of rolling stock, for the character of the prevailing traffic may lead to the building of special types of wagons different from what would be adopted if decisions were based solely on general considerations. To increase the capacity of wagons may prove advantageous in certain circumstances for certain goods, and for certain companies, but to recommend an increase in capacity as a general solution would be absurd. The average haul in Great Britain is very short, probably less than 40 miles, and this has a great bearing on the cost of haulage, as it affects the earning capacities of locomotives and rolling stock. As a result of the rapid transits given by British railways traders have gradually cut down their stocks to such an extent that they now order just sufficient for their immediate requirements, thus the average consignment only weighs 2 to 3 cwt., and the average truck load about 2 tons. This reduces the daily weight passing between any two points, and thus precludes the use of larger wagons than those now utilised, the ratio of dead-weight of which is abnormally high. Larger wagons of less dead-weight per unit of paying-weight have been tried, but found only to be economical between a limited number

* "The Economics of Railway Transport" (S. C. Williams, B.A.). P. 128.

of large towns as, in many instances, if a full load can be given in one direction, an unequal volume of traffic passing in the reverse direction creates extremely light loads on the return journey.

The number of axles on a train is of considerable importance as, speaking generally, the less the number of axles on a train of a given weight, the smaller the train resistance and the less the wear and tear of the road. This argument in favour of the high capacity wagon should, however, be qualified; vehicles with a rigid wheel-base undoubtedly cause a good deal of wear and tear of rails on curves, which would be obviated to some extent if wagons were fitted with bogies, as these are more flexible and, as a consequence, easier on the road. From a permanent way point of view, therefore, the greater the proportion of bogie stock in use the better.

The choice of a judicious unit for the size of stock has a material influence on the cost of working, and it is a great factor in the determination of rates. The question should be considered in connection with the local circumstances of each line, such as climate and produce of the district, mileage and configuration of the line, and disposition of the traffic. The dead-weight of vehicles should, of course, be reduced so far as this is compatible with safety and good maintenance. All railways (even those having wagons of less than 10 tons) recognise the advantages of having large wagons for the relative proportionate reduction in tare, and try to obtain these advantages by improving the ratio of tonnage carried to tare, as this leads to economy both as to cost of running and prime cost.

As an abstract economic proposition, the large capacity wagon is undoubtedly the best, for, in

general, the mean utilisation per ton available becomes greater as the mean tonnage per wagon increases. Further, it enables the tractive power of the locomotive to be better utilised. In the case of a train which is to carry a given homogeneous load, the number of wagons will fall a third or a half, according as the vehicles of which the train is made up have their tonnage increased 50 or 100 per cent. Moreover, trains consisting of large wagons are shorter, and are started and stopped more quickly; this not only reduces the delay at stations, but also the time required for the conveyance, hence the total carrying capacity of the line is increased. Since, however, as we have seen, the general tendency is for the retail business to become more pronounced, it would appear that the railway companies might do more to secure economic wagon loads by the encouragement of large lots, and by offering special inducements and making exceptional arrangements to ensure the return loading of wagons. The conclusion to be drawn from this is, that judicious experimental rates put in operation for the purpose indicated, are highly economical, and should, where the conditions are suitable, result in a considerably better ratio of "paying" to "dead" weight.

As regards mineral wagons, the companies are, perforce, restricted from instituting economies, owing on the one hand to the limitations fixed by the majority of the colliery screens and by many of the shipping staithes, and on the other hand by the large preponderance of private owners' wagons. The latter, in themselves, constitute a bar to economical operation owing to empty haulage back to pit—perhaps the most uneconomical factor in English train operating.

"Which is the more economical, the possession by the railways of all rolling stock or the possession by private owners of wagons?" asks M. L. Byers, in his book, "Economics of Railway Operation." "Every railway manager is aware of the great cost that is involved in sorting wagons, with their hundreds of different owners. By having wagons wholly in the possession of the railway, this cost is to a large extent obviated. On the other hand, however, the private trader is often disposed to think that the possession of rolling stock required for his own particular traffic gives him a greater control over the working of that traffic, and ensures in a higher degree the essential qualities of quicker transport and punctuality. The complications that arise from traders' and companies' wagons being so mixed up as to render impossible any intelligent analysis of the result of working—so far, at least, as the relation of rolling stock to the traffic carried may be taken as a basis—originated in, and has been perpetuated by, the fiction which regards railways as toll-takers only."

THE PROBLEM OF WAGON DISTRIBUTION.

In order to obtain the maximum utility of goods and mineral wagons, a defined system of distribution and control is essential, but it would be impossible to lay down certain rules as applicable to all railways and all districts. The most efficient method of distribution on each system is that which best suits the prevailing conditions, since it is a gradual outcome of those conditions; it is influenced to a great extent by the disposition of the traffic, the available rolling stock, the situation of the lines, and by the peculiarities of the different systems. There are two general systems of distribution in operation—viz., (1)

control, and (2) running, and as the former is more generally applicable to British railway organisation, this will first be considered.

For the purpose of "control" distribution, the line must be divided into districts, each under one man, who must again be subject to a central control. The district rolling stock inspector must each night be in possession of facts showing the stock on hand and required for the next day's use at every station in his district. Thus he will be in a position, by means of the telegraph and train messages, to order surplus stock from one station to another and to instruct the concentration yards as to the disposal of stock passing into the district. The central control is necessary for the supervision of the work of the inspectors and the even circulation and distribution of stock as between the various districts and, more particularly, for the centralisation of responsibility for the supply of necessary stock.

It is essential that the rolling stock controller should have a fairly accurate knowledge of the kind of traffic dealt with at the different stations, the usual number of wagons arriving and the tendency of outward traffic, as well as the accommodation at each, the extent of which may render it more or less necessary that the goods should be dealt with rapidly. It is essential, also, that the movement of empty wagons should be regulated in such a way that they do not cross one another, and that the empty train mileage is not increased unnecessarily; that certain wagons should not get too far away from the points where they are likely to be required; and, on the other hand, that the important centres should be constantly relieved of their superfluous wagons so as to prevent congestion when the outward traffic has begun to

decrease in volume, and when empty wagons might be a source of inconvenience.

Owing to the distinct limitations in their interchangeability, the number of boiler, machine and armour-plate wagons must be kept down to the limits of the ordinary requirements of the whole of the line, and it is important that these wagons, as distinct from ordinary stock, should be subject to distribution only by the central control, which must in each case be advised of their dispatch and destination; thus may the receiving stations be urged quickly to release and to send direct to the next station requiring the user.

To ensure the fullest possible economical benefit from the system, it is essential that yard masters and depot inspectors should at all times co-operate with, and obey the orders of, the district rolling stock inspectors in the matter of stock distribution, and also that the stations' daily stock reports should be accurately compiled and their information reliable. The advantages of the division into districts are that an efficient and personal supervision is exercised over the stations and a reliable estimate obtained of exact requirements. "No one," states Dewsnup, "can say how much might be saved, or how largely the earnings of railways might be increased, if wagons were handled economically, judiciously, and expeditiously,"* and it would appear that this system, properly followed, results in the maximum utility of wagon stock, owing to the impossibility of its being kept empty on hand at stations and to the influence exercised for obtaining its prompt release.

Another of the functions of the central control is

* "Railway Organisation and Working." E. R. Dewsnup.

the fixing of the requirements of the line in the matter of new stock. In this connection it has always to be remembered that the inability to meet demands for the supply of stock for loading at point of origin is to a great extent caused by "block" and congestion of the running roads, and any considerable increase in the wagon stock has, therefore, to be considered in conjunction with the possible effect such increase may have upon the present working of the railway.

The distribution of wagons by a distributing agent can only be said to be systematic when it affects the whole of the rolling stock. It would, therefore, appear that the division of responsibility as between goods and mineral wagons has a tendency to unduly increase the empty haulage, and prevent the more complete utilisation of both classes of stock. Further, it necessarily involves a duplicate organisation which could be avoided were the control centralised.

The principle of the system of "running" distribution consists in each station being obliged to despatch at once to some fixed destination every wagon for which immediate use cannot be found. Wagons sent forward in this way can be dropped on the journey at stations where they are required, except in certain cases when that arrangement is suspended. The great advantage of the system is that wagons are never left standing idle. They never have to wait for orders as to their destination. The fact that the stations have power to withdraw empty wagons from a train for their use lessens the tendency to keep wagons standing idle, as they can help themselves to others from a passing train.

This method of distribution is automatic, though

less so than it would appear to be. A great deal of watchfulness and foresight is required to see that the volume of return empty traffic is always in proportion to the requirements of the moment. It should be stopped, restricted, or increased according to circumstances, else the stations get blocked up with too many wagons on the one hand, or do not get supplied with a sufficient number on the other.

This method is most suitable on a system where the centres requiring the greatest number of empties are situated close to one another in the same district, and it seems to be the only suitable distribution method when the rolling stock is very considerable. It also allows of locomotive power being utilised to the best advantage, for, as empty wagons may be sent by any train, a proper load can be made up without waiting for instructions. As a set-off to these great advantages, "running" distribution has the disadvantage that, when the stream of empty wagons is reduced by an increase of traffic, it cannot be depended on with so much certainty as under the "control" system. This state of things can, however, be remedied by adopting exceptional measures at such times, as, for instance, by withdrawing wagons from the stream, and sending them to the points where they are most needed.

The best rules for the distribution of rolling stock combine in variable proportions the method of "control" distribution, and the method of "running" distribution.* The gradients of the lines and the position of the rolling stock should be taken into account, and the rules should also be capable of being adapted to the fluctuations of the traffic.

* "*Vide* Report to the International Railway Congress, Paris

Chapter XI.—ORGANISATION OF OPERATING DEPARTMENTS.

General Review—Traffic and Goods Departments—Locomotive Running and the Traffic Department—Conclusions.

The organisation of railways must necessarily be discussed in a series of papers devoted to the economic aspect of railway working, for, as Dunn points out,* inefficient management makes operation needlessly expensive; and, in the long run, whatever tends to increase the cost of operation tends to increase the rates that the public must pay for the transportation service.

Any intelligent consideration of the question as to whether a railway or group of railways is efficiently managed must be preceded by definition of the word "efficiency." The term is quite commonly used in the discussion of railway affairs as if it were synonymous with "economy"; but economy is not the same thing as efficiency. The public demands, and rightly so, that the railways shall not only be economically operated, but that they shall give good service. Efficient operation may, therefore, properly be defined as the rendering, as economically as may be practicable in the circumstances, of such service as best furthers the public convenience and welfare.

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* "The American Transportation Question," P. 125. S. O. Dunn.

English railway organisation is essentially departmental. Each profession, as we may term it, has its own department, the separation between traffic, goods, mechanical engineering, and civil engineering being very distinct. In the process of time ideas become very deep-rooted, so that alterations in existing arrangements are but slowly effected. Thus it is that although departmentalism, beyond certain limits, may—in conjunction with actual working—be considered undesirable, English railways have been slow to revise previously existing arrangements.

Organisation, to be efficient, must evenly distribute the burden of responsibility in such inter-relationship between individuals or departments that the various units comprised may each be affected and interested in the general scheme and its operation.

GENERAL REVIEW.

These papers being primarily on the subject of railway operation, it will be well to consider the organisation therein involved. The general English arrangement, with its superintendent, its goods manager, its engineer and chief mechanical engineer, is too well-known to be enlarged upon. The point of demarcation between these departments is severe; they have but few concrete interests beyond their immediate spheres of operation.

The superintendent has perforce to consider first and foremost prompt departures and punctual arrivals, speedy marshalling, shunting, etc. The goods manager must see to economical handling of goods, whatever the means employed, and quick delivery to his customers. The chief mechanical engineer's responsibility lies in the efficient working

of engines and their maintenance, whilst the engineer is concerned in the provision and maintenance of suitable track. Each has his own separate staff of employés working with the primary idea of effecting good results in the department by which they are governed.

Decentralisation of departments is necessary in the interests of both supervision and discipline. The district officer is necessary for the personal supervision of staff and working. To exercise efficient control he must have sufficient authority, and such authority is only rendered possible by the bringing of all matters to his notice; therefore, the district office staff is a necessity. Consequently, the question to be considered is, what is the most economic and yet effective organisation.

In this connection we may at once give voice to our belief that one of the greatest drawbacks to economic railway operation is departmentalism; as far as possible the barriers existent between the various departments must be removed by the process of unification of supervision. Further, decentralisation of control, though necessary, tends to increase clerical work, and it should, therefore, be carried out on the broadest possible lines.

TRAFFIC AND GOODS DEPARTMENTS.

As we have previously observed, the point of demarcation between the traffic and goods departments is somewhat severe, the duties of the former being primarily the transport of passengers and goods from place to place, and those of the latter, the handling of goods and charging for carriage

The unification of the control and supervision of

these two departments has, on one or two systems, been successfully effected by the initiation of the position of district traffic manager. an appointment covering the former duties of the district superintendent and district goods manager. This officer may have two assistants, viz. : (1) an operating assistant in control of all " outside " work, *i.e.*, traffic working and the handling of goods, and (2) a commercial assistant, in charge of the " inside " work, *i.e.*, rates and charges for passengers, parcels and goods, including canvassing, claims and all communications with the public.

Several advantages are naturally attendant on the revised system of organisation, amongst which may be cited the following :—

(1) " Departmentalism " between former goods and traffic departments annulled.

(2) Superfluity of clerical work at stations avoided.

(3) Reduction in supervisory inspectors and district office clerical staff.

(4) Reduction in the number of highly paid posts. The area of supervision covered by the district traffic manager with his two assistants may naturally be larger than the sphere of an ordinary district superintendent's control. The location of the district office must be central to the district, or division, which it covers, and, further, should also be situated at some important point of activity. In all matters affecting the handling and charging of goods traffic, the district traffic manager will be subservient, of course, to the chief goods manager, and in those connected with traffic working to the superintendent of the line.

The second revised form of organisation, which has been instituted on some lines, is already well known.

This also has for its object a division under the headings of "operating" and "commercial," but this, as distinct from the arrangement just outlined, is effected in a general manner. The general superintendent, for instance, is at the head of the operating branch, with a staff of divisional and district superintendents. He supervises general train working, compilation of time-tables, goods handling, stations, yards, etc., and distribution of rolling stock. The commercial branch is subdivided under the control of a chief goods manager with district goods managers and agents, and a chief passenger agent with assistant passenger agents. The responsibility of the chief goods manager is involved in the canvassing and charging for goods traffic, collection of information as to trade developments, rates, claims, cartage, etc., whilst that of the passenger agent lies in the fixing of rates and fares for coaching traffic, issuing of tickets, excursion traffic, advertising, supervision and control of booking and parcels offices, collection and delivery of parcels traffic, canvassing and claims.

Although this arrangement may be considered a laudable one in so far as it concerns the division of work into the logical spheres of the conduct of and charging for transportation, there can be no doubt that the division is an unequal one having regard to the resultant overwhelming amount of work and responsibility of the operating as compared with the commercial department. There is another primary objection in the fact that arrangements made with the public by one department have to be effected by another, and in such cases "departmental" interests are apt to be studied at the expense of general policy. Thirdly, there would appear to be a preponderance

of district officers, such as to encourage "departmentalism" and obviate economic decentralisation.

LOCOMOTIVE RUNNING AND THE TRAFFIC DEPARTMENT.

Having alluded to the operative and commercial division of supervision from the point of view of the district organisation on the one hand, and of the general organisation on the other, we will now proceed to a consideration of one of the most debatable points in present-day English railway organisation. We refer to the question of the control of locomotive running by the traffic operating department. On those railways where the "running" work is still in the hands of the locomotive department, there is constant friction with the traffic department on the question of engine loads. From their own departmental standpoint, perhaps each is justified, the one for attempting to decrease train miles by loading engines to their highest capacity, and the other for attempting to secure as many engine miles as possible for engine hours in steam.

Should, or should not, the supervision of locomotive running, at present covered exclusively by the locomotive department, be placed under the traffic department, and if it should, how far is such supervision to apply? These are the questions which we have to consider.

In the first place, the traffic (or operating) department is responsible for the efficient working and running of trains. Of the train crew, however, the guard only is under traffic control. The guards (through the medium of their journals) and the signalmen, depot inspectors, etc., can be referred to

in the case of working delays, but if these appear to be due to time lost by locomotives, another and separate department must be communicated with, whose word has generally to be accepted. Again, owing to the distribution of supervision, drivers can, at times, afford to ignore the instructions of the yard master and to differ from the opinion of the guard, even though these two functionaries may be actuated by reasonable and appreciative motives. Further, the constitution of the train service and the timings of the trains are vested in the duties of the traffic officer. From these considerations it seems but natural and logical that the traffic, as the responsible department, should have a voice in the working and running of the locomotive.

Turning, however, to the other side of the question, one immediately encounters the necessity for the exercise of technical supervision and knowledge as to the capabilities and efficient maintenance of the machine. Under existing arrangements this can be well maintained, even at the expense of traffic working, for the locomotive department is primarily responsible for efficient locomotive maintenance, and in the strain after perfection in this direction the requirements of the traffic may partially be overlooked.

True it is that the present practice admits of consultation between the two departments in matters of timing and loading, and whilst a complete transference of locomotive running work to the control of the traffic department would perhaps be inadvisable, it would certainly appear that a closer merging of the two departments, for the sake both of better supervision and enhanced efficiency in train operation, is necessary.

The possibly desirable course would, therefore, be the placing in the hands of the traffic department of the control of the engine from the time of its departure from shed to the time of its return. For this purpose the district traffic manager could have a technical assistant capable of advising him as to what may, or may not be, suitable performances having regard to engine, load, and road, in order that deficiencies in this respect might be immediately and directly taken up with the parties at fault, instead of having to pass through the present prolonged process from department to department.

CONCLUSIONS.

We, therefore, arrive at the following conclusions :—

(1) Decentralisation of the supervision of railway operation is essential.

(2) The unification of the supervision of operating and commercial matters in connection with decentralisation is desirable.

(3) The area covered by the district traffic manager must extend so far as to enable the maintenance of effectual supervision.

(4) The location of the district office must be central to the district and, if possible, at the point of maximum activity.

(5) The district traffic manager should have immediate control over the running, *per se,* of engines stabled at the depots in his district, and should be aided in this respect by a technical assistant.

With regard to the road and supervision of track maintenance, it is needless for us to comment on the fact of the American practice of placing this division

of railway work under the surveillance of the operating department. Although the efficient maintenance of the road is essential to economic train operation, the responsibilities of the engineering department are definite, and though slightly interwoven with those of the traffic department, are not interdependent in actual operation, as are those of the locomotive department. Technicality here also prevails, and the present arrangement for the vesting of sole responsibility in a chief engineer and district assistants is one which, under English conditions, can hardly be improved.

Chapter XII.—STATISTICS.

Passenger Trains—Goods Trains—Goods Terminals—Locomotive Operation—Representation of Statistics.

If a railway is to be managed with maximum economic efficiency, it is essential that certain statistical information be collated and synchronised; for it is futile to base judgments on arbitrary assumption if any degree of accuracy is to be attained. Hence our intention to discuss the merits of the various data obtainable for the purposes of comparison of railway operating results, or, in other words, the statistics of operation.

That statistics are necessary for the efficient working of a railway is a well-established fact; but the form which these statistics should take has been the subject of controversy between experienced railwaymen for many years. Statistics are most misleading in the hands of persons unacquainted with the true value of each service and each figure, for, as Prof. Dewsnup states, "statistical material is highly dangerous to handle, and even those familiar with its treatment have to act with the utmost wariness and discretion."*

Averages at all times are unsatisfactory data, for an apparently useful average unit may often be created by the assembling of conflicting figures, but this might not indicate economical operation. Bear-

* "Necessity of Care in the Interpretation of Railway Statistics used Comparatively." E. R. Dewsnup.

ing this in mind, we will discuss in their varied aspects the statistics pertaining to the several services of operation, *i.e.*, passenger train, goods train, terminal and locomotive operation.

PASSENGER TRAINS.

The statistical information usually obtained in connection with the working of passenger trains is the cost of operation per passenger train and the revenue per passenger train mile. Generally speaking, it is difficult to imagine any more useful average figure, especially when data for the different classes of trains, *i.e.*, express, stopping, and suburban, are respectively obtained. Owing to the marked similarity day by day in the engine power requisite for each train over a given stretch of line, with defined schedule times, cost of operation can fairly easily be computed. Not so, however, with revenue, which may be and is derived from "through" tickets used by passengers partly on fast and partly on stopping trains, thus rendering accurate computation most difficult, and, in the case of season tickets, practically impossible.

In connection with passenger train statistics a word may be said for the "Vehicle mile," as a unit of comparison. This, being the product of the number of coaches by the number of miles traversed, is easily obtainable from the guards' journals, which show the composition and the points of origin and destination of each train.

Many of our foreign contemporaries advocate the use of, and do actually produce, figures on the basis of passenger miles, *i.e.*, the cost of operation of and amount of revenue from one passenger conveyed

one mile. Although the figure tends to indicate whether trains are being fully utilised, it is apparent that, to obtain this average, the numbers of excursion, ordinary, and season-ticket passengers are commingled. Such figures must necessarily have a tendency to encourage the reduction of passenger services to a minimum, regardless of the interests of the public whom the railway companies serve. Therefore, although as a unit the passenger mile is more logical than the train mile, the advantages in its favour are so slight and the disadvantages so obvious, that it is questionable whether its comparative utility is equal to the considerable expense bound to be incurred in its computation.

Passenger train-mile statistics alone will not justify the discontinuance of any particular train; individual loading must first be studied. Then, also, it must be remembered that where well-filled trains run in one direction they must frequently pay for light trains in the reverse direction. Thus the railway manager cannot economically take off a train from A to B without also withdrawing one from the service B to A, unless he is prepared to run engines back light, a procedure which can scarcely be regarded as economical.

Figures indicating the result of passenger train operation, such as will serve as a basis for the consideration of the discontinuance of the worst paying trains, may be obtained from data covering prolonged periods, which may easily be furnished by guards through the medium of their journals, showing the number of passengers utilising the trains day by day, although this statement will more accurately apply to corridor trains, throughout which the guard has easy access *en route*, than to the ordinary

stopping or suburban services, where more precise information would be available from returns furnished by the collectors at the various stations showing the number of tickets collected from each train.

GOODS TRAINS.

The compilation of the statistical information connected with passenger train operation does not by any means create the many difficulties bound to be encountered in satisfactorily recording the results of goods train operation. The great difference between the two is exemplified by the fact that whilst the cost of hauling a passenger train from A to B is practically the same every day, except for the variation—which may readily be calculated—in the cost of hauling fast and slow trains, the cost of operation in connection with goods trains varies enormously owing to the ever-changing conditions of conveyance: load, capacity of engine, time occupied, etc.

The classification of the cost of different grades of trains is rendered extremely difficult, because one train may travel from A to B in an hour, whilst another may take six hours. With the times occupied by other trains varying between these periods, it is not possible to decide on a definite cost of operation for a given train over any particular district, for such factors as "user of the road" and others are composed of many indeterminate elements. Considering, then, the cost of goods train operation, the fluctuating expenses on the conveyance of the traffic are almost all combined in the train itself, the expenses of signalling, maintenance of way, and interest on the constructional cost of the line being

practically fixed, and varying but slightly with the quantity of traffic.

An analysis of the operating cost would disclose the following constituent elements :—

(1) Interest on capital cost of locomotive,
(2) Repairs to locomotive.
(3) Enginemen's and guards' wages,
(4) Coal and water;

but whilst (1) is a fixed charge, (2) varies according to the load hauled and the nature and amount of work performed, (3) according to time on duty, and (4) according to mileage, load hauled, and nature of road traversed. Cost of haulage, therefore, varies according to :—

(a) Weight lifted,
(b) Mileage traversed,
(c) Grades and curves encountered,
(d) Locomotive running time;

and so we have the choice of two averages, one of hours and the other of mileage. But the expenses enumerated do not vary in the same ratio as either time or distance, and it, therefore, becomes necessary for both train hours and train miles to be simultaneously considered in any attempt to formulate a reasonable comparative statement.

The train mile or engine mile cannot be used as the sole unit, because the cost of hauling a goods train 1 mile is not a constant, its variations being exemplified in the previously quoted example. Similarly, the train hour or engine hour is not a reasonable unit, *per se,* because the expenses per hour do not coincide—besides which one engine may represent twice the capital cost of another—though probably they more nearly approximate than the expenses per train mile, particularly if the cost of coal

consumed per unit of traffic is considered at the same time. Turning to revenue, greater difficulties than ever are disclosed. Figures may be obtained showing receipts per train mile, per wagon mile, and per ton mile, but on analysis it will be seen that each of these bases varies. The train mile may represent the haulage of 40, 50, 60, 70, or 80 wagons 1 mile, a general disadvantage which similarly applies to the train hour, and renders this figure of little practical value.

Directly opposed to these figures, the ton mile indicates the haulage of 1 ton 1 mile, a ton of coal, of grain, of sundry goods, for instance, the receipts from each of which vary in the ratio of (approximately) 1 : 3 : 6, taking as a basis ½d. per mile for coal as an average, and the maximum rates for conveyance in Classes C and 3. The cost of operating coal, grain, and sundries also varies, but in an inverse ratio, owing to the fact that a wagon loaded with either of these commodities, the cost of conveyance of which is approximately the same, will contain about 10 tons of coal, 5 tons of grain, and 2½ tons of sundries.

This varying ratio of cost (4 : 2 : 1), together with the inequality of the relative receipts, would, therefore, appear to indicate that weight (in itself) is not a satisfactory basis for statistical comparison, and that the cubical capacity of the vehicles conveying the goods is a factor of greater utility, for the normal cost of operating each loaded wagon (as a wagon) is generally admitted to be a fairly constant quantity when compared with the revenue, taking into account both tonnage and rate. But the wagon mile does not solve the difficulty, for the same deficiency exists in the wagon-mile figure as in all

others, that is to say, the conditions of operation differ essentially between the haulage of a wagon up a heavy grade and on a level road; through a district of high traffic density, and on a branch line.

Moreover, the dimensions of wagons vary considerably, and so does their utility. Bolster wagons, for instance, though essential for the particular traffic which they are constructed to convey, involve considerable empty haulage, owing to the infrequency of opportunities for back loading. Likewise, braked wagon stock may be marshalled into trains travelling at high speeds, whilst unpiped wagons may not be conveyed at more than 30 miles per hour. It may, therefore, be stated as an axiom that the greater the interchangeability of the stock the greater its utility and the smaller the amount of empty haulage. All these factors go to show the variations in the wagon mile as a unit of transportation.

The wagon mile does, however, appear to have many advantages over both the ton mile and train mile, and as, in addition, it enjoys the asset of being almost as easily ascertainable as the train mile, it may well be recommended. To make the best use of the statistics, the figures for stretches of line operated under similar conditions should, as far as possible, be considered separately, and thus overcome to some extent the vitiated comparisons consequential on the use of averages.

Cost and revenue statistics based on either of these units do not, however, show in half-a-dozen figures whether a railway is being operated economically, and whether present results are better or worse than comparative periods. Other important figures, as enumerated, are deserving of

close study, as their synchronisation affords valuable data :—

Statements of train loading.
Statements of wagon loading.
Coal consumed per engine hour.
Coal consumed per engine mile.
Time occupied by trains standing at signals.
Time occupied by trains in shunting.
Number of hours during which trains do not cover more than 10 miles.

The information contained in these statistics is of considerable utility to the railway officer, and as their preparation and subsequent utilisation have a great moral effect on the operating staff, and as, also, the figures—with the exception of those relating to fuel, which are discussed later—can readily be compiled from guards' journals, or by a modification in the form thereof, their use is to be commended. Easily ascertainable, also, from the same source, are the number of train miles per train engine hour. This statistic is undoubtedly of considerable utility as a basis for effecting improvements in train operation.

In considering marshalling and shunting yards from the statistical point of view, the most satisfactory figure is undoubtedly the number of wagons dealt with per engine hour, but as it is impossible reasonably to compare the operation of one yard with another owing to difference of lay-out and working, the value of such a figure is somewhat vitiated, though it may be said to be a useful comparative unit in an individual connection.

GOODS TERMINALS.

The cost per ton of goods handled is the usual statistic employed to record particulars of the loading

and unloading of goods, but this figure suffers from the same weakness as most averages, viz., that an increase in tonnage of low-class traffic reduces the average cost per ton of the whole, or vice-versa, and so renders false deductions possible. If it is really necessary to have statistics of this class of work—beyond figures which will exercise a moral effect on the staff—and presumably it is, the records should clearly separate the different classes of traffic and show the time of the men employed on each class in proper correspondence.

No useful purpose is served in ascertaining the cost in one figure of dealing with (1) Miscellaneous "C and D" goods loaded or unloaded across the stage, (2) "C and D" traffic dealt with in yard, (3) "S to S" traffic dealt with in yard, and (4) heavy "S to S" traffic dealt with by cranes. It is statistically desirable, therefore, separately to record these classes of traffic, and this can most easily be done in divisions 2, 3, and 4 by the checkers recording each wagon-load in detail and the time occupied thereon, and in division 1 by locating the amount of such traffic dealt with at a station, and comparing this with the men's time.

Whilst the periodical tonnage and expenses statement, in general use by most companies, affords an excellent means whereby those at the head may keep a check on the cost of handling at the various depots, it is also necessary in each case to ascertain the cost of cartage. This is important, as it will often happen that in one yard carters' wages will be abnormally high in proportion to those of the goods handling staff, whereas in another yard, similarly situated as regards accommodation and traffic, precisely opposite conditions will prevail,

for the following very obvious reason: in the first case, instead of the transfer of goods from stage to dray and vice-versa being performed by the goods staff, this work will be done by the cartage staff, the goods staff merely barrowing to and from the dray, with a resultant low cost of handling. In the second instance, the goods staff will not only barrow the goods, but will load up the dray, so that on the drayman's arrival his load is practically ready, this naturally causing a relatively high cost of handling on goods staff account.

To give a complete record of the cost of working a yard, therefore, the tonnage and expenses statement should not only show cost of handling, but also cost of cartage per ton. Furthermore, attention should be paid to the amount of transhipping work performed at the goods depot, as costs tend to increase consequent on the double handling which tranships necessitate.

Another unit of considerable utility in connection with the comparison of goods depot working, subject, of course, to the conditions and restrictions already enumerated, is the tonnage handled per man hour, this being the product of the division of the tonnage handled by the total number of hours worked in each case.

Apart from these figures, which have exclusive reference to the handling of goods, it is essential that wagon loading records should be compiled, and the statements indicated below are of great utility as proving the efficiency or otherwise of supervision :—

Number and weight of full load consignments.

Number of foreign wagons loaded home.

Number of high capacity wagons and weight loaded.

Average load of other wagons.

In comparing the figures for one goods depot with those of another, consideration must always, of course, be had to the particular description of traffic dealt with at each. One depot may have a preponderating heavy-class traffic easily and expeditiously handled by special appliances, whilst another may deal largely with "smalls" and light traffic, such as hosiery and leather, entailing considerable barrowing and handling. Figures, therefore, in such cases are no criterion!

LOCOMOTIVE OPERATION.

The expenses of locomotive operation are, to an extent, included in the costs of train operation, but these are limited to actual running expenses, wages of enginemen, cost of coal, etc., and though these are the essentials, the costs of maintenance demand systematic inspection or considerable waste may result. In this matter it seems desirable that complete data should be obtained, and carefully analysed, in order to determine whether it be more economical to run engines for all they are worth until shop repairs are essential, or spend more in running repairs and have less frequent shop repairs. The appropriation of men's time and materials is of considerable worth and utility, and the returns embodying this information should in every instance receive the utmost attention, as their careful analysis and comparison will elucidate many facts necessary to effect further economies.

Another point: in any considerable increase in the loading tables efforts should be made to ascertain the additional cost of enhanced boiler and general repairs rendered necessary thereby, and also, if

possible, the effect of the increase on the life of the locomotives.

A further figure compiled in connection with locomotive operation is the cost of coal per locomotive mile or per locomotive. But this would appear useless for comparative purposes, since any variation in the price per ton, quality of the coal, size of locomotives, or changes in operating or traffic conditions have such influence as to render it valueless as a basis for comparing performance, although its tendency, when published, to encourage a spirit of competition amongst enginemen for the attainment of best comparative results, is a factor which should not be ignored.

REPRESENTATION OF STATISTICS.

The form in which statistics are presented is of considerable importance, and reasonable judgment in this regard will be well repaid by the greater facility with which the statistics may be interpreted. Figure comparisons are apt to be wearisome and to exhibit an absence of emphasis, so that more effective illustration may at times be demanded. Thus, diagrammatic representation enables the busy man to see at a glance comparative results, which would take far longer to grasp when embodied in columns of figures. By the aid of parallel lines—one plain, representing one year, one dotted, representing a previous year—plotted through a graph, with vertical and horizontal indications, variations in receipts, expenditure, mileage, or whatever may be represented, can immediately be ascertained, and there is doubtless considerable call for this method of representation.

Chapter XIII.—STATISTICS—(*Continued*).

A Criticism of the Ton-mile Figure—The Composition of the Ton-mile Figure—The Ton-mile as a Unit of Operation—Ton Miles ÷ Route Miles—Average Haul and Average Receipt per Ton—Average Train Load—Ton-miles per Train Hour—Conclusions.

In discussing railway operating statistics in their general aspect, we have purposely refrained from entering closely into the question of the ton mile figure, considering that so very debatable a subject merits separate and more exhaustive treatment.

A CRITICISM OF THE TON MILE FIGURE.

The ton mile figure which, as its name implies, gives the cost of operation of, or revenue from, 1 ton conveyed 1 mile, may at first sight be concluded to consist of the total tonnage multiplied by the total miles of railway. This, however, is quite incorrect, as the major portion of the tons only use a portion of the railway, and to obtain the figures it is, of course, necessary to analyse the traffic passing over the line for which the statistics are required.

So many foreign railways compile these figures that biassed critics of British railway administration have concluded that English railways are too

conservative, or, on the other hand, are afraid that the publication of statistics modelled on the ton mile unit might give away the secrets of their trade, the fact that two important trunk lines compiled the statistics for years and finally abandoned the practice as they were found to be of no practical utility being entirely ignored. That the American railways, though they are required by law to prepare these figures, do not attach much importance to this "unit of public service"--as the ton mile statistic is popularly termed in America—is apparent on perusal of an article by Professor Ripley of Harvard on "The Course of Railway Rates Since 1870," in which he says: "The changes in receipts per ton mile do not accurately determine the general tendency of rates in this country . . . and a comparison of the revenue per ton mile of the various American railways shows how, owing to the preponderance of the respective traffics differing in kind or conditions, some companies receive .75 cents per ton mile and others 1.4 cents."

The advantages claimed for ton mileage are that, once provided, so many useful figures can be immediately obtained, and the following tabulation, extracted from Mossop's "Railway Operating Statistics," indicates the uses to which the advocates of ton mile statistics put the figures :—

		Results.
Ton miles ÷	Route miles	Average density.
	Tons	Average distance.
	Train miles	Train load.
	Train hours	Ton miles per train hour.
	Shunting hours......	Shunting cost per revenue unit
	Loaded wagon miles	Wagon user.
	Engine stock	Engine user.
	Weight of coal consumed................	Coal per revenue unit.

THE COMPOSITION OF THE TON MILE FIGURE.

Before discussing the supposed utility of these derivatives of the ton mile statistic, we will first ascertain the various elements which enter into the ton mile factor. This comprises: (1) Local traffic which could be summarised and the tonnage, mileage, and receipts ascertained at sending station; (2) traffic forwarded to foreign lines the tonnage and mileage of which could only be obtained at sending station, and the receipts accruing to the company concerned after the division; (3) traffic received from foreign lines, the tonnage and mileage of which could only be obtained at receiving stations, the receipts accruing to the company concerned after division; and (4) traffic passing from one foreign station to another foreign station over an intermediate line. In this case, neither forwarding nor receiving station would calculate figures for the intermediate line, and particulars of tonnage and receipts could only be obtained through the Clearing House.

It will thus be seen that tonnage could be obtained by the company concerned in the first three cases, receipts only in the first, and that the assistance of the Clearing House would be required for the tonnage in the last instance, and the receipts in the last three cases. No doubt it is possible to obtain the information, but this must, of necessity, be three to six months late, as the abstracts periodically rendered to the Clearing House by the railways would have to be analysed, an operation which would take a long time and cost a huge sum. And statistics, to be useful, should be to hand promptly!

The carriage of 1 ton 1 mile includes the con-

veyance of 1 ton of coal, 1 ton of grain, or 1 ton of wickerwork, the revenue derived from such transport varying in the ratio of the rates charged; the cost of conveying a given number of tons might represent the haulage of one wagon of coal, two wagons of grain, or ten wagons of wickerwork. The conveyance of 1 ton 1 mile may occupy an hour or five minutes; it may be hauled up a heavy gradient, on the level, or down a bank. How can such diverse conditions be merged in one factor with due equity?

Assuming that practically all statistics are subject to objections, corrections, and provisions, the difficulties attendant on the varying nature, weight, and bulk of the commodities would appear insurmountable. But no! The ton-mileacs have a remedy as, by taking out, at great expense, the weight and receipts for each commodity or class of commodities, they ascertain (a) the tonnage of (say) coal, grain, groceries, etc., carried 1 mile, and (b) the average rate per ton per mile charged for each class of commodity. At first sight, the average rate of (say) grain would appear to be a most useful figure, and of great utility in the fixing of rates, but as rate making is influenced by such determining features as distance, water competition, the exigencies of trade, and the necessity of equalising prices at competing markets, the average rate is found to be of no practical value.

If, for some special reason, a large quantity of grain is carried a long distance at a very low rate per mile, the average rate is pulled down, and the inexperienced might think that the rate on grain traffic between A and B should be reduced to this level; but this would be absurd.

THE TON MILE AS A UNIT OF OPERATION.

The cost of operation per ton mile is not always the same; it is, in fact, probably true to say that it differs in every instance. Weather has an effect on it, and gradients and density of traffic vary the figure. It would certainly be interesting to know the cost per unit over a certain length of line and compare it with the cost per unit over a similar length; but what is the use of placing the traffic on up grades, down grades, busy sections, and light sections in one figure and considering the result accurately reflects operating cost? It averages operating cost, to be sure, but is the average of utility?

Moreover, the unit of operation is not, as fallaciously supposed, the ton—without consideration of its bulk. All tons do not cost the same to convey, and do not bring in the same revenue; neither, of course, does a cubic foot of carrying space; but we would aver that the wagon mile per engine hour—a readily obtained unit—is far more indicative of what is being done than the ton mile. With this unit, however, it is necessary to have a thorough knowledge of the conditions, as the value of AVERAGES is often negatived by practical circumstances.

TON MILES ÷ ROUTE MILES.

It is claimed that the product of this division gives the average density of a line, and whilst this is approximately true, we fail to perceive the utility of such a figure. It is of little interest to have the AVERAGE density. This cannot be utilised as an operating unit. What is wanted is the density on heavily worked lengths of line. It is quite useless

commingling this figure with the density on branches where only ten trains pass per day.

The use of ton mile statistics in this connection would, superficially, appear to be advantageous, but as the ton mile includes small heavy goods, and goods of a bulky character in proportion to weight, the theoretical utility of the average density figure is substantially diminished, as no allowance is made for the difference in conditions.

For example, 50,000 tons of minerals might be conveyed in 5,000 10-ton wagons, and worked in 100 fifty-wagon trains, the gross weight hauled, assuming a tare of 6 tons per wagon, being 80,000 tons. On the other hand, the carriage of 50,000 tons of lighter commodities would necessitate the running of 20,000 wagons, assuming a reasonable wagon-load to be 2½ tons, thus requiring 400 fifty-wagon trains, and a gross haulage of 170,000 tons.

How, after consideration of such a disturbing factor as here exemplified, can the supposed utility of the ton mile unit be justified? Where conditions are diametrically opposed to each other, as in this instance, the only effective means of watching the density of traffic is by the wagon mile. It costs almost as much to haul an empty wagon as a loaded one, and it is, therefore, on this figure—the wagon mile—that density can best be appreciated.

AVERAGE HAUL AND AVERAGE RECEIPT PER TON.

By dividing the ton miles by the tons conveyed the average haul is obtained, and whilst this figure may be of academic interest, and useful to those uninformed individuals who seek every opportunity to revile railway administration, we cannot conceive

its serving any practical purpose. It is said that a knowledge of the average haul and the average receipts would be of service in connection with rates, but this would appear a fallacy, as no *average* can be taken as a true basis on which to build a general factor.

Rates must be fixed in accord with the particular conditions and to meet the requirements of trade. No railway manager would say to a customer : " The average rate on this line is X, so your rate will be X." The principle of not charging the traffic more than it can pay must be borne in mind, as it is on this principle, and this alone, that traffic will move. Moreover, the cumulative scale of charging vitiates any true indication of the average receipt. As the charges vary for distances of 20 miles, 50 miles, 100 miles, and so on, it would not be possible for any average to be of utility. Again, the effect of terminal charges, in connection with local, foreign, and through-through traffic must be taken into account, as must also the services and facilities included in some, but not in other, rates.

AVERAGE TRAIN LOAD

Another much vaunted figure derived from the ton mile statistic is the average train load, this being the product of a division of ton miles by train miles. Why the advocates of the "new form" should support this is a question. What is the use of such a figure when the maximum train load on a level road is (say) seventy wagons and on an up grade (say) forty-five wagons? The merging of such figures would appear to defeat the whole object of statistical information—the simplification of opera-

tion. If traffic on the level road predominates, a high average train load results; if the situation be reversed, the average train load is reduced.

How absurd it would be to compare the average train load of a company whose line runs through flat country with a similar figure of a company whose line has heavy grades and high density! The result would be most misleading. Only those who have studied railway operation closely can understand the far-reaching effects of these different conditions. The majority would probably accept the figures at sight and draw invidious comparisons which, on careful analysis, would generally be fallacious.

TON MILES PER TRAIN HOUR.

This figure, again, does not permit of reliable comparison, because many of the ton miles have produced twice or thrice as much revenue as others, and cost of operation differs owing to the varying number of wagons necessary for the conveyance of (say) coal and wickerwork.

In applying the ton mile figures to requirements of stock, we are again met with difficulties owing to fluctuations of traffic. It would undoubtedly be useful to know from statistics the minimum number of wagons required to conduct efficiently the business of a railway, but, unfortunately for the success of any statistical unit, the amount of traffic offered for conveyance varies between particular seasons of the year; traffic is usually heavier in one direction than the other, wagons are retained under load, and time is required to permit empty stock to be hauled from places where there is no demand to centres where they are required.

CONCLUSIONS.

Superficially, ton mile statistics appear useful, but the more one attempts to apply them the more does one feel that, owing to the variation in conditions, their value is very questionable, and that they are more liable to confuse than simplify operation.

Though England is practically isolated in successful resistance to the adoption of these statistics, it cannot be said that the railway managers are unduly prejudiced. The ton mile unit has been tested and found wanting, and it would appear that the majority are convinced that the disturbing factors in English railway practice, such as the proportion of joint, leased, and worked lines, the running powers exercised by numerous companies, the frequent pooling of traffic irrespective of route, etc., would render the compilation of ton mile statistics an extremely expensive and unsatisfactory business.

CHAPTER XIV.—THE OUTLOOK.

Co-efficients of Operation—The Tractive Factor—Rail v. Road Transport—Rolling Stock—Signalling—The Staff—State v. Private Management.

The whole economic proposition of successful operation is the realisation of the highest possible amount of productive work for the unit of cost. It behoves us, therefore, before discussing prospective economic developments, to examine the factors co-related with the ratio of operating expenditure to receipts, and so endeavour to arrive at some real basis for the comparison of results and the institution of economies.

CO-EFFICIENTS OF OPERATION.

The ratio of operating expenditure to receipts—known on the Continent as the co-efficient of exploitation—is worthy of special study. On no two railways are these ratios similar, and even were such the case, no reliable comparisons based on such figures could be formulated with the differing conditions and circumstances of traffic. It is said that the ratio of operating expenses to gross earnings is the fundamental basis of comparing efficiency in operation. The fallacy of this argument may

readily be shown—if any presumption is needed to demonstrate the futility of using, for a measure of efficiency, a mathematical ratio between two quantities, one of which may vary independent of any factor of efficiency of operation—as when earnings rise because of higher rates on an unchanged tonnage traffic.*

From a commercial point of view, a railway enterprise naturally divides itself under three separate heads, viz., (1) First cost, (2) gross receipts, and (3) working expenses. Given these three items, and the character of the railway as an investment may readily be determined. The working expenses, however, show more than this. They afford a clue, in their details, to the comparative economy or extravagance with which a railway is managed, to the source of possible leakage, to the higher or lower comparative prices of materials and costs of labour, to the greater or less expense attending the various descriptions of traffic, and to other points that are of more or less importance in their relation to the efficient administration of the transportation system.

Such being the case, it is obvious that in considering the many problems that are continually presented for settlement in relation to railway control, the expenses of working the different systems are entitled to a foremost degree of attention, being, in point of fact, next to gross receipts, the determining factor alike of rates, fares, profits, and efficient service.†

The charging powers of railways are restricted by the Railway Rates and Charges Order Confirmation Acts of the early 'nineties, amplified by the

* "Railway Operating Costs." Suffern and Son.
† "Railway Problems." J. S. Jeans.

Railway and Canal Traffic Act, 1913, and as the charges for conveyance are separated from those leviable for terminal services, it is perforce essential that terminal expenses should not exceed the proportion of the rate allocated to such services. On the other hand, the expenses of actual train working (including the operation of sorting sidings, etc.) have to be covered by conveyance charges, and it is here that one of the great difficulties of railway management is encountered.

In practice it is impossible to ascertain the exact cost of conveying any given consignment, firstly, because of the joint cost nature of the function; secondly, because trains have to run in accordance with schedules whether there be, say, 150 tons or 250 tons to be hauled; and, thirdly, because as traffic increases to the point of the highest operating density, the railway's general expenditure (i.e., general charges, maintenance of way and works and of rolling stock) remains practically constant, and thus, as the receipts increase, a smaller proportion of the fixed charges need be allocated to each unit. The average manufacturer is able to calculate, relatively speaking, what each unit produced costs him, but this is not so with the seller of transportation.

The difficulty is exemplified by the application of the argument to a ship, which advertises a sailing and risks the amount of cargo; on one voyage she is well loaded, but on the next she carries a light cargo. Interest on capital, depreciation, and practically all other expenses are the same on the two voyages, and shipping companies may thus lose on certain voyages. They are not, however, tied down to maximum rates, and their rates—to an extent—fluctuate as the demand for space increases or

decreases. Similarly, the demand for space in one direction is greater than in the other, and the rates, therefore, vary in accordance with the laws of demand and supply. A ship, moreover, unlike a railway, is not tied to certain spheres of operation, but can turn to other and more remunerative ones by transferring its service from or to other ports.

In view of the fact that the receipts per unit of traffic cannot, owing to Parliamentary restrictions, be increased in times of bad trade the transportation business suffers more than all others, not only for this reason, but because, in addition to fixed charges remaining constant, operating costs are but slightly reduced in bad seasons. The public, to whom the railways owe a duty as well as to their shareholders, are not concerned with the question of cost. They require prompt deliveries of their goods when trade is slack in precisely the same way as when trade is brisk, so that it is not always possible to avoid dispatching the same number of wagons as formerly. Though the number varies but slightly, the load in each is considerably lighter, and thus less revenue is derived, although the cost of operation remains practically constant.

Operating costs, therefore, are dependent on several factors, each bearing a percentage to the whole, which, on an average railway, may briefly be placed as follows:—

(1) General charges ... ... 5 per cent.
(2) Maintenance of way and works... 19 per cent.
(3) Maintenance of rolling stock ... 18 per cent.
(4) Locomotive and traffic expenses 58 per cent.

General charges, involving, as they do, Directors', officers', and headquarters staff's salaries, maintenance of estate property, etc., will scarcely alter,

whatever be the increase in the traffic. These charges, moreover, vary much more in relation to mileage than to traffic. Similarly, a large proportion of the cost of maintenance of way and works does not in any way vary with the amount of the traffic, e.g., station and other buildings become renewable owing to natural depreciation. The cost of the maintenance of the permanent way itself is not materially affected by the traffic passing over it, for it must necessarily be kept in perfect condition, whether there be a large or small traffic. With regard to rolling stock, wear and tear is the result of movement, so that depreciation occurs whether wagons be fully or only partially loaded; moreover, owing to the ever-changing conditions of railway transport, rolling stock gradually becomes antiquated, rendering it necessary for the greatest possible use to be obtained from it in the shortest possible time.

Of the actual expenses of operation a large proportion remains the same whether the line be one of high or low traffic density. The operation of sorting sidings, once constructed, varies but little, although it should be stated that until the extent of the traffic necessitates sorting sidings on a large scale, limited accommodation only is provided, and this gradually increased to meet the requirements of the business. At the same time, if traffic decreases, operating costs are but slightly affected. The expenses connected with signalling maintenance and working vary but slightly whether 100 or 150 trains use the particular stretch of line each day, and it is only when a certain density is reached that it becomes necessary for additional appliances to be adopted.

The only charges which vary in the same or a similar ratio to the traffic are those for locomotive

power, interest on working stock capital, and a portion—perhaps one-half—of the traffic (including terminal) expenses. Even here it is questionable whether their varying quantity is entirely affected by the volume of traffic, inasmuch as engine power and stock have to be provided to meet the requirements of the normal maximum demand, so that, when business is slack, a portion is unproductive, but the interest on the cost thereof has to be met.

Thus we see the considerations which should be borne in mind in comparisons of operating costs and results. In connection with prospective developments in the railway service, one must necessarily turn first to the means utilised in the movement of trains, and consider the tractive factor in all its bearings.

THE TRACTIVE FACTOR.

Though the steam locomotive has long held supremacy, and with the recent additions to its faculty of utility, still presents a serious obstacle to its tractive competitors, one cannot ignore the fact that the recent developments in motor transport, the great and remarkable improvements in electric traction, and the introduction of the internal combustion locomotive must be regarded with respect by all concerned in the economic operation of railways.

The primary disadvantage of the steam locomotive lies in the fact that, under the best conditions, it can only satisfactorily utilise about 60 per cent. of the available heat in the fuel, the remaining 40 per cent. being wasted in heat losses, as described in our paper on "Locomotive Design and Practice." As a matter of fact, its useful capacity was less before the advent of the superheater, but even as it stands, it

should be apparent that such waste must be lessened, or, on the other hand, more economical methods adopted.

There are two recognised means of supplying power for practical railway requirements, though to the steam locomotive and the electric motor must now be added the internal combustion engine. In this connection it is interesting to observe that just as the electric motor was suggested as a rival to the steam locomotive, so now the internal combustion engine is pitted against the electric motor. The fundamental principles which underlie the problem of train movement, *per se*, are the same in either instance, but a true comparison of their relative advantages can only be made by a study of each particular method. The self-contained steam locomotive has its counterpart in the internal combustion engine, which, worked on the unit system, is declared by its advocates to be a more economical tractor than the centrally-controlled electric motor.

The subject of electric traction is of very live interest to railwaymen from the standpoint of possible economies in existing operating methods in the fact that not only may it constitute an economical tractor, but that its force of energy may be converted to other uses. Signalling improvements are, by stress of circumstances, constantly being advocated, and in each case these—designed on definite lines to restrict or eliminate the element of human fallibility—are all operated by the virile force of electricity.

Let us, then, state the present development of the three tractors. The steam locomotive, of powerful design, is now built to the full limitations of the loading gauge, and, aided by the latest scientific devices, may probably have reached its highest stage of eco-

nomic perfection. On the other hand, the electric motor is in many places gradually displacing the steam locomotive. Not only is this apparent on urban lines, but on main lines its introduction is progressing. In America particularly it is well established, and not only is it utilised for passenger services, but also for goods services; indeed, the future may bring forth a general utilisation of self-contained electric locomotives worked on the accumulator system. In the third case, a Diesel locomotive, weighing 85 tons, is now in regular goods service on the Prussian State Railways.

RAIL V. ROAD TRANSPORT.

There is, however, another side to the possibilities of the future, since the motor vehicle has attained such a high stage of development. Is it possible that the railways, which superseded the canal and road means of conveyance, will themselves be rendered nugatory by the re-establishment of road transport?

The recent prophetic article which indicated the final demise—in 1950—of the steam locomotive, and the substitution therefor of specially designed high-speed motor units which, operating on the defunct railroads—then converted into smooth roads—are to convey the whole of the traffic of the country, may well be considered illusory, but it indicates at least one clear fact, viz., that motors, under certain conditions and in specified places, may be of great utility. Though it is inconceivable, so far as one is able to judge, that motor, i.e., road transport, should ever re-establish its old-time position, and should be rendered capable of conveying the millions

of tons of goods now passing over the railways, it is by no means impossible that within a few years their use may rapidly be extended for passenger transport. The rapid growth in the power and capacity of motor vehicles and their extreme mobility are swiftly popularising this form of transport, and once the cost can be brought within reach of the masses, the railways will surely feel the effect.

From London the motor 'bus services are spreading farther and farther afield, and already is the effect of their competition being felt, 15, and even 20, miles away from the metropolis. Owing to the use of public roads by motor vehicles they are relieved of the necessity of returning interest on capital cost of way and works, and the consequent cheap fares, coupled with the attraction of fast rides by road, serve to draw legitimate rail passenger traffic from its normal course, traffic which, owing to the specialised road over which it travels, has to pay, besides actual transportation costs, its fair share of interest on capital invested in the railroad. Thus we see how impossible it is for railways effectively to compete with suburban road motor services, when the railways themselves have to bear, through taxation, a large proportion of the cost and maintenance of the verv roads over which their competitors operate.

For long-distance passenger traffic it is doubtful whether motor vehicles, as fare-charging mediums, will ever seriously affect the splendid system of fast and luxurious passenger trains, unless and until special roads be constructed for their sole use, and even then they will not have the extent of punctuality and reliability possessed by the railways, though it cannot be denied that their use is rapidly

being extended for pleasure tours, particularly in the neighbourhood of seaside and inland pleasure resorts.

As a factor of utility in connection with railway business there is doubtless scope for the motor vehicle. Good use of this method of transport is already made by several railway companies, and no doubt their sphere could, in certain localities, profitably be extended. As a feeder to existing lines of railway in connection with the passenger business, and as a substitute for the construction of branch lines likely to be long unremunerative, their use may be invaluable, whilst if the vehicles could be suitably strengthened and their rate of depreciation thereby lessened, they might well be utilised by the railways to expedite the transfer of relatively short-distance goods traffic. In such an event their use might be the means of effecting economy in a double sense, viz., by retarding the necessity for extensions and widenings rendered essential—under ordinary conditions—by the development of short-distance traffic, and by the more speedy transit of long-distance traffic through the lessening of congestion, although it must always be remembered that the cost of upkeep of a motor service is very high, particularly when the service is restricted and limited, as in the case of a railway enterprise.

ROLLING STOCK.

Whilst the subject of rolling stock has been rather fully discussed in a previous paper, we may here call attention to the present tendency in this country to consider the construction of "all-steel" cars. Though until lately in vogue in America, recent accidents in this country have given rise to the sug-

gested advisability of the adoption of passenger rolling stock composed of less inflammable and more unbreakable material than at present is the case, and one railway company is already experimenting with a train of all-steel cars in daily working. The two primary considerations in this connection appear to be questions of weight and expense. Whilst the former is an important factor on the hauling capacity of the locomotive, the latter is one that must be dealt with in conjunction with a further problem, viz., whether the likelihood of the recurrence of train accidents in this country, with its splendid system of signalling, substantial permanent way and reliable works, is so great as to warrant the additional constructional expense.

SIGNALLING.

In present-day signalling systems there is a constant effort to dispense more and more with the "human element." One has heard a lot recently with regard to the Angus system of signalling, whereby it is claimed to be impossible for a train to run past a signal at danger, the mechanism of the installation itself bringing the engine to a stand, even though the driver fail. This system, though having numerous points to recommend it, might possibly tend to engender a careless attitude on the part of the driver, who, even if the safety of those working on the line alone be considered, should at all times maintain an efficient look-out.

The Board of Trade's recommendation is that "some reliable mechanical contrivance should be provided to notify to a driver that he is running past a signal at danger," and it is by no means an essential factor that the arrangement adopted should be

of an intricate character, as the greater the intricacy the greater the expense and possible fallibility. This is the great disadvantage of the majority of the patents which have recently been invented to meet the purpose, and there seems to be a call for a simple attachment to be fixed to the mechanism working the signal whereby, when at danger, the signal may be covered by a fog signal in position on the rail, this "fog" being mechanically removed when the signal is pulled off. With such a system, of course, the fog signals would have to be well-nigh infallible, and even then would probably need changing at frequent intervals.

THE STAFF.

Perhaps no field in the wide range of railway operating offers greater problems than does the staff. Evidence from all sides points to the fact that we are undergoing the comparatively gentle phases of a revolution, and the workers are steadily gaining more ground. This perhaps—and we do not wish to cavil—is as it should be; we are quite at one with the man who wishes to be adequately and fairly paid in proportion to the quantity of his productive work, but there is a limit, and this limit is strictly bound by the railway companies' ability to pay, which in its turn is restricted to the sources from which the necessary money can be obtained. The English railways are at a disadvantage in this matter compared with their Continental neighbours. Maximum rates in England are necessarily bounded by the competition afforded east, west and south—particularly the latter—by the sea, whereas in large continents such a competitive element does not exist.

However, a very great deal can be done by the

exhibition and encouragement of greater sympathy between employer and employed. More and more is this sympathetic feeling being promulgated, and appreciation of it on the part of the employés is gradually being evidenced. If the workers can only be made to understand that the progress of the undertaking in which they are engaged is a vital and all-important factor in their own welfare, that each unit should strive to work for the good of the whole, then great progress will have been made.

The difficulties connected with the institution of a scheme of co-partnership are many, but possibly they are not insurmountable. Even without it, great strides could no doubt be made in the directions we have indicated.

STATE V. PRIVATE MANAGEMENT.

Some there are who believe that the panacea for all railway troubles is to be found in the management of the railways by the State. They suggest that such a change would effect economies in operation, in administration, in management generally. By the elimination of competitive trains and of departmental duplication, and the substitution therefor of an *official* system, such a change would be justified, so it is argued. The fact is ignored that other countries, having the complete control of their railways, require the assistance of hordes of officials, the expense of which is probably equal to that of those engaged on the private lines of Great Britain.

Then, it must be remembered that State railways are less amenable to reason, more difficult to impel, and certainly more arbitrary in arrangement than privately-owned railways worked for profit. As M.

Colson observes: "The public does not take into account that a commercial undertaking, worked for the sake of profit, frequently understands better how to satisfy the requirements of its patrons than a less elastic official enterprise. Neither does it appreciate that it is better for the community to be sometimes in conflict, as passengers or consignors of merchandise, with shareholders over-anxious for dividends, than be compelled to pay, in the shape of taxation, for unnecessary facilities provided by a State service under électoral influences."

It is questionable, therefore, whether the nationalisation of railways is likely to prove so ideal an arrangement as some believe, and though the purchase of the railways by the State would appear to be the ultimate result of the Government's refusal to permit amalgamations, it is to be hoped that such a drastic step will not be taken until the railway question has been thoroughly investigated by a competent and impartial body.*

The railways of Britain have been built by private enterprise, and have been brought to their present high stage of development by the same means, despite the somewhat arbitrary restrictions of the Legislature. That their sphere of usefulness could be extended there is no doubt, and it is a fitting conclusion to a work on operating economics to voice the belief that the direction in which the railways could most swiftly and surely reach a higher stage

* Since the preparation of this paper has appeared the interesting announcement of the appointment of a Royal Commission, whose terms of reference are "to inquire into the relationship between the railway companies of Great Britain and the State in respect of matters other than safety of working and conditions of employment, and to report what changes, if any, are desirable in that relationship."

of economic perfection is by a policy of amalgamation.

The possibility of monopolistic autocracy could be guarded against by judicious legislation, and as such amalgamations would have all the advantages and none of the disadvantages of State ownership, they would appear to form the next logical stage in the development of British railways.

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